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IDENTIFIERS	Caribbean; *Mars (Planet); Scientific American Frontiers; *Spiders

ABSTRACT

These teaching guides are intended to supplement the shows of the ninth season (1998-99) of the PBS Television Series "Scientific American Frontiers." Episode 901 is entitled "Science in Paradise: Another Side of the Caribbean." The teaching guide contains information and activities on hawksbill turtles, volcanic eruptions, playing the steel pan, the world's largest radio telescope, and sea fans--a dying species of soft coral. Episode 902 is entitled "Journey to Mars: Getting There--and Back." The teaching guide includes information and activities on the Martian atmosphere, the possibility of ancient life on Mars, and various aspects of interplanetary exploration and space travel technology. Episode 903 is entitled "Animal Einsteins: How Smart Are They?" The teaching guide features information and activities on communicating with animals through sign language, the connection between language and thought, monkeys and chimpanzees with simple mathematical abilities, problem-solving ravens and tamarins, assessing animal intelligence, and communication between chimps and monkeys. Episode 904 is entitled "Life's Little Questions--and Some Very Big Answers." The teaching guide contains information and activities on hot peppers, insect aerodynamics, jet lags, traffic jams, and materials science. Episode 905 is entitled "Spiders!" The teaching guide contains information and activities on how spiders spin webs, spider strategies for outwitting enemies, the evolution of a new spider species, spider colonies, and arachnophobia. Each lesson topic is matched to the relevant national science education standards. (WRM)

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Scientific American Frontiers Teaching Guides for Shows 901-905 October 1998-April 1999

- **Science in Paradise**
- **Journey to Mars**
- **Animal Einsteins**
- **Life's Little Questions**
- **Spiders!**

Hosted By Alan Alda

GTE **PBS**

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SCIENTIFIC AMERICAN FRONTIERS

TEACHING GUIDE FOR SHOW 901
OCTOBER 7, 1998 • 8-9 P.M.

Science in Paradise

Another Side of the Caribbean

GTE

Corporation

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SCIENTIFIC AMERICAN FRONTIERS

Show 901:
Science in Paradise

October 7, 1998 • 8 p.m. on PBS (CHECK LOCAL LISTINGS)

Host Alan Alda accompanies scientists near St. Croix in an underwater search in a coral reef to capture a hawksbill turtle, pictured here. This turtle and many others are being tracked in their travels as part of a conservation project. Join Alan for the premiere of this season's SCIENTIFIC AMERICAN FRONTIERS as he and the crew tour the Caribbean in this special international episode, uncovering science stories in island sites from Puerto Rico to Trinidad.

5 TURTLE TRAVELS

The hawksbill turtles that nest on the beaches of Buck Island off St. Croix are turning out to be a classic conservation success story.

RUNNING TIME: 12:28

ACTIVITY: Comparing nesting temperatures

6 PARADISE POSTPONED

Life on the tiny, lush island of Montserrat has been forever changed by deadly eruptions of a volcano dormant since the time of Columbus.

RUNNING TIME: 9:15

ACTIVITY: Model a mini-volcano

7 THE PAN MAN

Alan learns to play the steel pan — believed to be the only acoustic instrument invented in the 20th century — in its country of origin, Trinidad.

RUNNING TIME: 10:28

ACTIVITY: Good vibrations from steel spoons

8 BIG DISH

Visit Arecibo, Puerto Rico, home of the world's largest radio telescope — a 1,000-foot dish tuned in to signals from all parts of the universe.

RUNNING TIME: 7:57

ACTIVITIES: Build a reflecting dish; risk assessment

10 DUST BUSTING

Scientists dive into the Caribbean to find out why sea fans, a soft coral, are dying. The problem begins half a world away, in Africa.

RUNNING TIME: 11:02

ACTIVITY: Capture microbes in the air

Plus, in every issue . . .

4 VIEWER CHALLENGE

Guided viewing quiz questions, T-shirt prizes!

11 FRONTIERS ONLINE

Visit us at www.pbs.org/saf/

ON THE COVER: Buck Island off St. Croix, U.S. Virgin Islands.

SCIENTIFIC AMERICAN FRONTIERS is made possible by an underwriting grant from GTE Corporation. The series is produced by The Chedd-Angier Production Company in association with *Scientific American* magazine and presented to PBS by Connecticut Public Television. Classroom materials produced by Media Management Services, Inc.

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This year, in response to your feedback, we have added a new feature (below) that helps you see at a glance the correlations between SCIENTIFIC AMERICAN FRONTIERS television programs and teaching guides and the National Science Education Standards. As always, we'd love to hear your comments about this and other aspects of the School Program. *(See contact information below.)*

"IT'S JUST SCIENCE AS INQUIRY, MR. HAYNES."

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
ENVIRONMENTAL SCIENCE **LIFE SCIENCE:** reptiles, reproductive strategies	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Reproduction and Heredity, Populations and Ecosystems, Diversity and Adaptations of Organisms; **9-12:** Biological Evolution, Behavior of Organisms / **SCIENCE AND TECHNOLOGY: 5-8, 9-12:** Understandings about Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Populations, Resources and Environments, Natural Hazards, Risks and Benefits; **9-12:** Population Growth, Natural Resources, Environmental Quality, Natural and Human-induced Hazards, Science and Technology in Local, National and Global Challenges

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
EARTH SCIENCE: plate tectonics, volcanoes **CHEMISTRY:** acid-base reactions **SOCIAL STUDIES:** Caribbean geography	**SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8:** Properties and Changes of Properties in Matter, Chemical Reactions / **EARTH AND SPACE SCIENCE: 5-8:** Structure of the Earth System, Earth's History; **9-12:** Energy in the Earth System / **SCIENCE AND TECHNOLOGY: 5-8, 9-12:** Understandings about Science and Technology / **SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES: 5-8:** Natural Hazards, Risks and Benefits; **9-12:** Natural and Human-induced Hazards, Science and Technology in Local, National and Global Challenges / **HISTORY AND NATURE OF SCIENCE: 5-8:** Nature of Science; **9-12:** Nature of Scientific Knowledge

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
CHEMISTRY: metals **SOCIAL STUDIES:** West Indies history **MUSIC** **PHYSICAL SCIENCE/PHYSICS:** acoustics, frequency, sound	**SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8:** Transfer of Energy; **9-12:** Interactions of Energy and Matter / **SCIENCE AND TECHNOLOGY: 5-8:** Abilities of Technological Design, Understandings about Science and Technology; **9-12:** Abilities of Technological Design, Understandings about Science and Technology / **HISTORY AND NATURE OF SCIENCE: 5-8, 9-12:** Science as a Human Endeavor

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
EARTH SCIENCE: asteroids, astronomy, meteors, space **MATH:** geometric shapes, probability **PHYSICAL SCIENCE:** radio waves, sound **PSYCHOLOGY:** risk assessment **TECHNOLOGY:** SETI	**SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8:** Transfer of Energy; **9-12:** Interactions of Energy and Matter / **EARTH AND SPACE SCIENCE: 5-8:** Earth in the Solar System; **9-12:** Origin and Evolution of the Earth System, Origin and Evolution of the Universe / **SCIENCE AND TECHNOLOGY: 5-8, 9-12:** Abilities of Technological Design, Understandings about Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Natural Hazards; **9-12:** Natural and Human-induced Hazards / **HISTORY AND NATURE OF SCIENCE: 5-8:** Nature of Science, History of Science; **9-12:** Nature of Scientific Knowledge, Historical Perspectives

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
EARTH SCIENCE: coral reefs, oceans **ENVIRONMENTAL SCIENCE** **LIFE SCIENCE:** bacteria, fungus	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Populations and Ecosystems, Diversity and Adaptations of Organisms; **9-12:** Interdependence of Organisms / **EARTH AND SPACE SCIENCE: 5-8:** Structure of the Earth System; **9-12:** Energy in the Earth System / **SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES: 5-8:** Populations, Resources and Environments, Natural Hazards; **9-12:** Natural Resources, Natural and Human-induced Hazards / **HISTORY AND NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge

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- ✔ Always check TV listings to confirm air date and time.
- ✔ If you can't find the show in your TV listings, call your local PBS station.
- ✔ Educators may photocopy all materials in this guide for classroom use.
- ✔ Do you need help? Call the FRONTIERS School Program at 800-315-5010.
- ✔ Videotapes of past shows can be purchased ($21.97 each). Call 800-315-5010.

LET US HEAR FROM YOU!

Do you have a comment or question about FRONTIERS? Do you know someone who wants to sign up for free teaching materials? PLEASE CONTACT US . . .
BY MAIL: SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425 • PHONE: 800-315-5010 • FAX: 215-579-8589 • E-MAIL: saf@pbs.org

SCIENTIFIC AMERICAN FRONTIERS is closed-captioned for the hearing-impaired and is narrated by Descriptive Video Service (DVS) for visually impaired audiences. The series and School Program are endorsed by the National Science Teachers Association (NSTA) and the National Education Association (NEA).

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VIEWER CHALLENGE

Science in Paradise

SCIENTIFIC AMERICAN FRONTIERS

Show 901 • October 7, 1998, at 8 p.m. on PBS (CHECK LOCAL LISTINGS)

Watch SCIENTIFIC AMERICAN FRONTIERS for answers to the questions on this page. Answer the 10 questions correctly and you'll be eligible to win a FRONTIERS T-shirt!

Reminder: Cover the answer key at the bottom of this page before photocopying.

Student's Name: _____

Teacher's Name & Course: _____

Turtle Travels

1. Unlike other sea turtles, hawksbill turtles have one special feature that's especially attractive to hunters and poachers, namely their:
   - ☐ a. eggs.
   - ☐ b. meat.
   - ☐ c. "tortoise shells."
   - ☐ d. beaks.
2. How do you put a sea turtle into a deep trance?

   _____

Paradise Postponed

3. When it erupts, the volcano on Montserrat releases a mixture of toxic hot gases, ash and rocks called:

   _____
4. To try to predict future eruptions, volcanologists measure the growth of this part of the volcano:
   - ☐ a. caldera.
   - ☐ b. lava flow.
   - ☐ c. fumarole.
   - ☐ d. dome.

The Pan Man

5. The steel pan or drum originated on the island of:
   - ☐ a. Tobago.
   - ☐ b. Trinidad.
   - ☐ c. St. John.
   - ☐ d. Bermuda.
6. Why are steel bands in Trinidad concerned about the future of the pans?

   _____

   _____

Big Dish

7. Unlike optical telescopes that detect light given off by stars and galaxies, radio telescopes tune into:

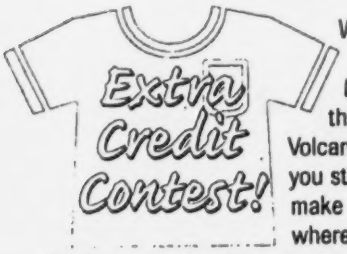
   _____
8. The Arecibo Observatory tracks stars and galaxies, and also analyzes very distant raw signals in a search for:
   - ☐ a. pulsars.
   - ☐ b. intelligent life.
   - ☐ c. supernovas.
   - ☐ d. aliens/comets.

Dust Busting

9. Sea fans, a soft coral and an important part of reef ecology, are being devastated by a common:
   - ☐ a. bacteria.
   - ☐ b. virus
   - ☐ c. fungus.
   - ☐ d. worm.
10. How did the disease-carrying organisms get to the Caribbean?

    _____

    _____



What would you do if you lived on Montserrat before the Soufriere Hills Volcano erupted? Would you stay on the island or make your home somewhere else? Why? Defend your position in an essay of 100 words or less and send it by **November 6, 1998,** to Extra Credit Contest at the address to the right. The most convincing arguments will be posted in the Polls & Prizes section of the FRONTIERS website and the winners will get a T-shirt. ***Good luck!***

FOR TEACHERS ONLY

When completed, this page can become an entry to the FRONTIERS T-shirt contest; 20 winners (10 students, 10 teachers) will be drawn at random for each show. To enter the T-shirt drawing, send all completed challenges in one envelope with a cover sheet to: Viewer Challenge, SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425. Mail completed entries by **November 6, 1998.**

TIP: You can download these questions on the Web: www.pbs.org/saf/

IMPORTANT!! Please include a separate cover sheet and tell us:

- number of challenges submitted
- teacher's name
- grade and course
- school name, address and phone number
- where your students watched the show — at home, at school or both
- the name of your students' favorite story in this show (conduct a quick poll to find out)

Thank you!

Answers to the Viewer Challenge: 1. c 2. rub its belly 3. pyroclastic flow 4. d 5. b 6. competition from loud rock bands and mass-produced steel pans; oil companies may stop using steel barrels 7. radio waves or radiant noise 8. b 9. c 10. they were carried by dust from Africa

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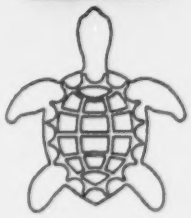
SCIENTIFIC AMERICAN FRONTIERS

TURTLE TRAVELS



On this episode of FRONTIERS, Alan Alda accompanies biologist Zandy Hillis-Starr into the waters of the Caribbean off St. Croix to capture an adolescent hawksbill turtle. Like other species of sea turtles, the hawksbill is endangered. Here at the Buck Island Reef National Monument, scientists capture and track hawksbill turtles as part of a successful program to preserve the species.

I'm Hot, You're Not

Research shows that for turtles, as for most reptiles, the cooler the temperature of the nesting site, the higher the number of males that will hatch. Warmer nests produce more females. Biologists must keep this in mind when designing artificial shade to replace the natural shade destroyed by hurricanes. In this activity, explore how different factors affect temperature and relate this to whether a baby turtle will be male or female.

MATERIALS

- ☐ outdoor thermometers (3 minimum)
- ☐ graph paper
- ☐ colored pencils

PROCEDURE

1. Find three dry areas on the ground near your classroom with the following characteristics:
   a. exposed to the sun all day
   b. exposed to the sun part of the day, shaded part of the day
   c. shaded all day

   Try to find sandy places to model turtle nesting sites. Look for sites that will not be disturbed by anyone but your class, or put a fence or barrier around the site.
2. Place a thermometer on the surface at each site and record the temperature. Record other factors such as clouds, precipitation and wind.
3. Continue taking and recording measurements every 30 minutes for the entire school day. You might have to share the responsibility with other science classes and pool the data to construct a complete data table for an entire day.
4. After you take the data, determine the high, low and average temperature for each site.
5. Using graph paper and a different colored pencil for each site, construct a line graph with temperature on the vertical axis and time on the horizontal axis.

QUESTIONS

1. Which area had the highest average temperature? The lowest? How did the environmental factors you recorded in Step 2 affect the temperature?
2. If a sea turtle built a nest at each site, which site would you expect to have more male hatchlings? Female? Why?
3. How do you think your temperature results would change if you chose sites that were kept moist? Design an experiment to test your answer.

Eggstrategy

Part of the hawksbill turtle's reproductive strategy is to return to the same beach every two years, lay hundreds of eggs and leave them to fend for themselves. Only a small number of hatchlings will survive, so it's important to maximize the number of eggs that hatch.

Working on your own or in small groups, use the Web or other resources to investigate reproductive strategies of selected organisms. Some good species to study might include: praying mantis, monarch butterfly, frog (any species), desert tortoise, hummingbird, rattlesnake.

Some animals, like the turtles, lay many eggs and abandon the nest, putting their faith in numbers; other animal species, like humans, bear fewer young but stick around to care for them and assure them a future. For the turtle, most of the energy is expended up front.

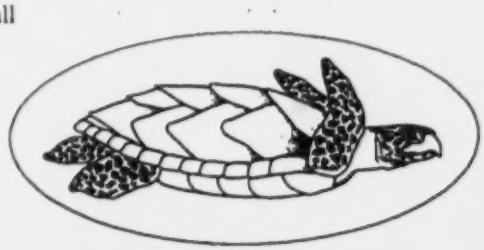
Present your findings to the class for comparison. Include information about reproductive strategies, gestation, breeding behavior of parents, developmental cycle of eggs, energy costs. What are the pros and cons of different reproductive behaviors?

EXTENSIONS

1. What is the advantage of being able to fit more eggs into one nest for the female laying the eggs?
2. Hawksbill turtles have been found as far south as Belize. How many miles/kilometers is Belize from Buck Island?
3. What might be the evolutionary advantages and disadvantages of having the gender of a species determined by temperature?
4. Fishing nets present a hazard for air-breathing sea turtles. If caught, the turtles may drown. Can you design a device that would keep turtles out of nets, yet allow fishermen to catch shrimp? For one example see the turtle excluder device at:

   kingfish.ssp.nmfs.gov/tmcintyr/turtles/teds.html
5. What should you do if you find a nesting sea turtle on the beach? Find out at:

   www.cccturtle.org/threats.htm#what



SEE PAGE 11

Biologist **Zandy Hillis-Starr** with the National Park Service at Buck Island answers your questions online. **www.pbs.org/saf/paradise.html**

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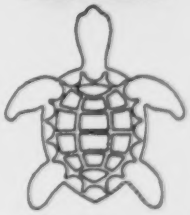
SCIENTIFIC AMERICAN FRONTIERS

PARADISE POSTPONED

In 1995, people living on the tiny, green island of Montserrat woke up to the early stages of what would become devastation: the long-dormant Soufriere Hills Volcano began sending out steam and ash, eventually burying much of the lush island in ash from deadly pyroclastic flows. Meet volcanologists who risk their lives as they keep a watch on the volcano.



Build a Mini-Volcano

When SCIENTIFIC AMERICAN FRONTIERS filmed this story early in 1998, most inhabitants had been evacuated from Montserrat. Those who remain on the island must live in an exclusion zone at the northern end. In July 1998, a few months after the story was filmed, Soufriere Hills erupted again. The dome seen on the show collapsed, sending toxic gases and hot ash into the atmosphere and down the mountain. Pyroclastic flows added to the new delta being created in the sea.

Many islands in the Caribbean are volcanic in origin; the region sits on top of an unstable subduction zone. You can't replicate an erupting volcano, but you can have fun making a chemical reaction with this model. And your job as volcano-watcher will be a lot safer than those you see on FRONTIERS!

MATERIALS:

- ☐ baking soda
- ☐ distilled white or regular vinegar
- ☐ modeling clay or Play-Doh®
- ☐ plastic plate or Masonite for base
- ☐ Alka-Seltzer® and red food coloring (optional)

PROCEDURE

1. Sculpt a mountain of clay about 9 cm high, using Masonite or other material for a base. Shape the mountain into a sloping volcano. (Make your mountain a different size, if you wish.)
2. If needed, let the clay harden. If you're using a soft modeling clay, it does not need to dry.
3. Scoop out about 1/3 of the top of the clay mountain to make a deep crater or hollowed-out section.
4. Place baking soda at the bottom of the hollowed-out cone.
5. When you are ready to watch your volcano 'erupt,' pour in a small amount of vinegar. Stand back and observe!

   NOTE: Experiment with the amounts of baking soda and vinegar used. Start with a small amount of baking soda (about 1 teaspoon) and vinegar (about 1/4 cup) and experiment with the ratio. The 'lava' will bubble up and overflow; when it stops flowing, add more baking soda and vinegar to keep it going.

   OPTIONS: Add red food coloring to the baking soda before pouring in vinegar. Drop in part or all of a crushed Alka-Seltzer® tablet for special effects. The chemicals in the tablet will keep the reaction bubbling longer.

SEE PAGE 11

Rick Herd from the Montserrat Volcano Observatory answers your questions online.
www.pbs.org/saf/paradise.html

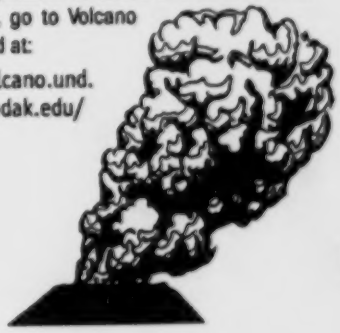
EXTENSIONS

1. Mixing baking soda (bicarbonate of soda) and vinegar creates a simple chemical reaction between an alkali or base (baking soda) and an acid. The chemical name for baking soda is sodium hydrogen carbonate; the chemical name for undiluted vinegar is ethanoic acid. What happens when a carbonate like baking soda is mixed with an acid? Carbonates contain carbon and oxygen. When the carbonate is mixed with an acid, the carbon and oxygen escape as carbon dioxide gas – the same gas you exhale when you breathe out. Ask a chemistry teacher to help you work out the formula for this reaction. What other combinations of acids and bases could make a similar reaction?
2. Our planet experiences many natural disasters – volcanoes, earthquakes, tornadoes, hurricanes, floods. More and more people build their homes in areas where natural disasters have happened. Would you? What are the trade-offs? For more on risk assessment, see page 9.
3. **MATH EXTENSION:** If the pyroclastic flow is moving at 100 mph, how far will it travel in four minutes? At 200 mph?
4. In the summer of 1998, we saw how disasters like forest fires or a tsunami can devastate a region. If you live near a natural disaster or other major hazard, create a disaster plan for the inhabitants.
5. Read updates of the South Soufriere Hills Volcano at:

   www.geo.mtu.edu/volcanoes/west.indies/soufriere/govt/

6. Two other famous stratovolcanoes that caused extreme destruction were Mt. Vesuvius, which erupted in A.D. 79 and destroyed the towns of Pompeii and Herculaneum, and Mount St. Helens, which erupted in Washington State in 1980. Like the Montserrat volcano, these volcanoes produced pyroclastic flows, a mixture of hot gas, rocks and ash that destroys all in its path. Gases in Earth's magma escape so forcefully that they blast hot rock into billions of particles (ash). To see pictures of active and extinct volcanoes, go to Volcano World at:

   volcano.und.nodak.edu/



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SCIENTIFIC AMERICAN FRONTIERS

THE PAN MAN

SCIENTIFIC AMERICAN FRONTIERS travels to Trinidad, where Alan Alda learns to play the steel pan, or drum, in the land where this acoustic instrument originated. Listen to the music of Trinidad's champion steel band, the Renegades. Then find out how to make a steel pan and "wake up" its notes, as demonstrated by master tuners.

Steel Sounds

Listen to the steel pan music on this episode of FRONTIERS. When the musician's stick hits the surface of a pan, the metal vibrates. These vibrations set nearby air particles in motion. When this motion reaches our ears, we detect it as sound.

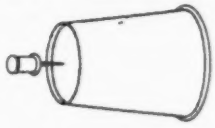
In this activity, you'll build a steel instrument. Your noise maker, however, won't be constructed from oil drums. Instead, you'll have to settle for stainless steel spoons. With this note-playing 'instrument,' you'll observe the effects of mass and tension on pitch.

MATERIALS

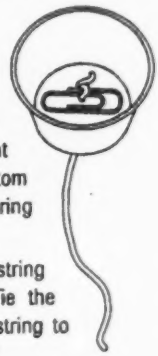
- ☐ stainless steel spoons of varying sizes. (Teaspoon and soupspoon sizes are ideal. Spoons made of aluminum will also work. Be sure to use old spoons no longer in service!)
- ☐ kite string
- ☐ 2 paper cups
- ☐ push pin
- ☐ paper clips
- ☐ scissors

PROCEDURE

1. Cut two lengths of string about 28 cm long each.
2. Use a push pin to punch a small hole in two paper cups. Each hole should be centered in the bottom of the cup.



3. Pass a string halfway through each cup.
4. Tie a paper clip onto the string end that extends through the inside of each cup. Pull the string taut so that the clip is pulled flat against the inside bottom of the cup (like a string telephone).



5. Tie the free end of one string to the small spoon. Tie the free end of the other string to the large spoon.
6. Place one cup over your ear. Its attached spoon should dangle freely.

7. Strike the hanging spoon with another metal or wooden utensil.
8. Describe the sound you hear. Listen to the sound that is made when you strike the other spoon. How are the sounds similar? How are they different?
9. Place a bend in the large spoon just below the spoon's bowl. Strike it again. Has the sound changed?
10. Place different bends in the spoons to produce a variety of pitches.

QUESTIONS

1. How does the large spoon sound compare to the small spoon sound?
2. Why does bending the spoon change its pitch?
3. What are two ways to change the pitch created by a vibrating object like a spoon or steel pan?
4. Why do the sounds produced by these vibrating spoons seem so loud?
5. What is the relationship between the area of the steel pan and the pitch of the note it produces?

PREDICT

Predict the relative pitch made by a more massive serving spoon. Once you've made your guess, check it out!

SEE PAGE 11

Engineering professor **Clement Imbert**, of the University of the West Indies, answers your questions online. **www.pbs.org/saf/paradise.html**

ANSWERS: 1. The large spoon produces a sound of lower pitch. 2. The bend places a tension in the metal that alters the frequency at which it vibrates. 3. Change the size or tension in the vibrating material. 4. Instead of traveling through air, the sound vibrations travel along the kite string. Since solid material is a better conductor of sound, it transfers a much louder noise. 5. The larger the note area on the pan, the lower the pitch it produces.

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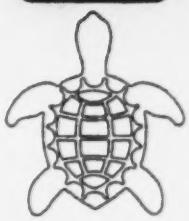
BIG DISH

Nestled in the hills of Puerto Rico, the Arecibo Observatory tunes in to the universe, searching for signals from distant space, using the world's largest radio telescope. Arecibo searches for pulsars and distant galaxies, listening for a signal that may indicate the presence of intelligent life elsewhere. The telescope also monitors the presence of asteroids, especially any that may be headed toward Earth.



Model a Big Dish

Arecibo is a huge dish 305 meters in diameter, shaped like part of a sphere and set in an ancient limestone crater. Most of Arecibo's work is radio astronomy — listening to and amplifying radio waves, enabling astronomers to discover stars and galaxies at the edges of the universe. A recent upgrade makes Arecibo ten times more sensitive than it used to be. In addition, its new, more powerful radar-emitting device can detect and create images of asteroids — especially those that might be headed toward Earth.

Arecibo and other radio telescopes are reflecting dishes that use curved surfaces to collect and reflect radio waves. If you have a satellite dish on your house or in your backyard, you are using a smaller version of a reflecting dish. Arecibo's "antenna dish" (the curved surface) collects and reflects signals. When radio waves strike the surface, they are reflected back through the focus (the dome), which concentrates the signals.

In this activity, you'll experiment with a curved reflecting dish that will work like the Arecibo detector. Then you'll use your model to detect electromagnetic waves.

MATERIALS

- ☐ radio (not a Walkman)
- ☐ appliance that produces radio static ("noise")
- ☐ cooking wok
- ☐ aluminum foil

SEE PAGE 11

Jim Cordes of Cornell University's Department of Astronomy answers your questions online.
www.pbs.org/saf/paradise.html

NOTE: Appliances that produce static include motorized toys, blenders, small electrical motors, grinders, microwaves, etc. Experiment with different receptors and static producers. If using a blender, mixer or microwave, remember to boil or blend water; do not run the appliance empty. You can use a digital or analog radio or a small TV and do not necessarily need a radio with an antenna.

PROCEDURE

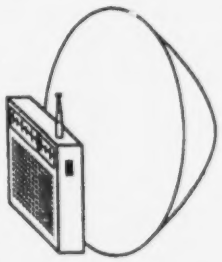
1. Line the bowl of the wok with several layers of heavy duty aluminum foil. Smooth the foil. Carefully remove the foil so it keeps the shape of the wok. This is your model of the Arecibo dish.
2. If your radio has an external antenna, push it in to its shortest length.
3. Switch on the radio. The instructor or another student should switch on a nearby appliance that produces radio static ("noise").
4. While the noisy appliance is running, move the radio next to the appliance and tune the radio to the static. (Note the difference between the background static and the static produced by the appliance; background static is more random, but the appliance static usually has a "pulse.")
5. When you have tuned in the static so it's distinct, slowly separate the devices until the static created by the appliance is no longer broadcast by the radio. You'll have to walk about 15 to 20 feet away from the appliance.

6. Hold the reflecting foil dish behind the radio so its bowl side faces the contracted antenna and aims directly at the appliance. How does the dish affect the static? (The foil dish should create static again.) Aim the bowl in different directions. How does the direction of the bowl affect reception? Does the distance to the antenna affect the static?
7. The wok is also spherical and can be used as a reflecting dish. Its smooth surface will concentrate the waves better than the foil, which, if it's crinkled, might reflect the waves in random directions. Try using the wok instead of the foil dish. How does the change affect reception?

What's going on here? The wok or foil dish is comparable to the reflecting dish at Arecibo. Signals that reach the Arecibo dish are collected and reflected back to the dome; signals reaching the tin foil dish are reflected and concentrated at the radio or its antenna.

EXTENSIONS

1. How might an umbrella lined with aluminum foil affect the detection of radio static? Make a prediction. Construct a reflecting antenna dish with aluminum foil and an umbrella. Test your detector. Can you detect local stations? Make a guess. Then, check it out!
2. Ordinary radio telescopes are constructed more in the shape of a parabola. Look for other examples of parabolas – from flashlights to car headlights. How might a parabola reflect radio waves?



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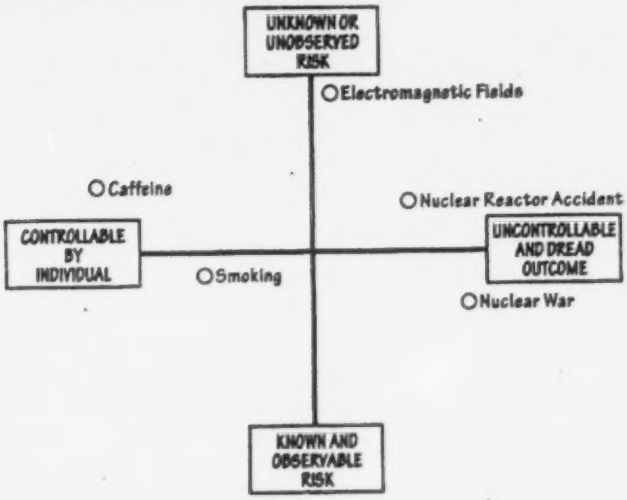
Risky Business

All risk is relative. Some risks worry us; some don't. Risk analysts try to understand our concerns by comparing and contrasting the controllable nature and seriousness of a risk. Examine the grid below. It is called a risk space. The position of each hazard was placed by a risk analyst. How concerned should we be about a possible asteroid collision with Earth? How does this risk compare with other risks we may be exposed to?



QUESTIONS

1. Do you agree or disagree with the placements of the various 'hazards'?
2. Is a collision with an asteroid controllable?
3. What are an individual's risks associated with an asteroid collision?
4. Will all asteroid collisions produce the same risks? What factors determine the seriousness of the risk?
5. Where would you place an asteroid collision on this grid?
6. If the odds of a 1 km asteroid hitting Earth are 1 in 1,000 in the next century, what are the odds for each year of that century?

NOTE: Students will have different views of where these hazards should be placed. Encourage discussion. Accept all reasonable answers that integrate both the control and observable nature of the risk. For more discussions of current issues in science, consult *Decisions Based on Science* available through NSTA.

Cosmic Collisions

It's often said that Earth exists in a "cosmic shooting gallery," because our planet is surrounded by asteroids, comets and meteors. Asteroids are pieces of space rock and metal, ranging in size from a few tens of meters to almost 1,000 km (600 miles) in diameter. Most orbit a region between Mars and Jupiter. If they cross Earth's orbit, they're called "Earth-crossing asteroids." Here are some factoids about asteroids and other cosmic collisions:

- ☐ The impact of an asteroid that collided with Earth 65 million years ago is believed to have killed more than 70% of all living species on the planet, including the dinosaurs. Scientists theorize that this asteroid, the K-T impact, was at least 10 km (6 miles) in diameter.
- ☐ Scientists have found evidence of more than 100 impact craters on the surface of the planet. A more "recent" (in geological terms) impact occurred in Arizona about 50,000 years ago, when a 10,000-ton iron meteorite hit the ground and formed Meteor Crater. And scientists believe a small, rocky asteroid no bigger than 60 meters (200 feet) exploded above Siberia in 1908.
- ☐ Hollywood movies about cosmic collisions are fun to watch, but do not present real science. Hundreds of years could go by before the next object of any significant size strikes the Earth. At the present, scientists are investigating ways to deal with an asteroid headed our way. One solution is launching a nuclear device to deflect the asteroid orbit off course.
- ☐ Scientists' predictions are sometimes wrong – as was the case in the false alarm created by Asteroid 1997 XF11 in March 1998 – but such an event demonstrates the need for good science.

How likely is it that Earth will be hit by an asteroid? Scientists have offered differing odds. Astronomer Steven Ostro, who you see in this episode of FRONTIERS, says there is a 1 in 1,000 chance that an asteroid 1 km in diameter or larger would collide with Earth in the next century. In the May 1998 issue of *Scientific American*, Philip Yam writes, "The odds that an 'extinctor,' an object two to five kilometers wide (about twice that of Asteroid 1997 XF11) will strike the planet this century range from about 1 in 1,000 to 1 in 10,000."

"Millions of real asteroids are out there, most of them uncharted, and one of them will hit Earth sooner or later. Finding a killer asteroid — or determining that one doesn't exist — would cost about fifty million dollars, less than half the budget of 'Armageddon.'"

— TIMOTHY FERRIS

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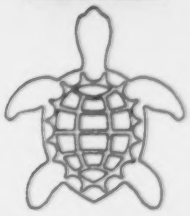
SCIENTIFIC AMERICAN FRONTIERS

DUST BUSTING



Coral reefs are part of marine environments in underwater communities from the Caribbean to Australia, but many reefs around the world are in serious decline. In this story, scientists work together to find out why one kind of soft coral, the sea fan, has become diseased. The problem begins half a world away, with dust blowing across the Atlantic from Africa.

Microbes, Microbes, Everywhere

Aspergillus fungi belong to a group of non-flowering plants known as imperfect fungi. There are several species. *Aspergillus niger* is the fuzzy black mildew sometimes found on preserved jellies. *Aspergillus flavus* grows on stored cereal products. Some species are even used to make antibiotics.

Follow the investigation on FRONTIERS to find out how the fungus gets to the bottom of the ocean. Then try this simple investigation to find out more about the microbes surrounding you.

Breathe deeply. Although you can't see it, you've just sucked in a microbe zoo. To a healthy organism, most of these germs are harmless. But as you see on FRONTIERS, under the right conditions (and exposed to the right host) some common microbes can cause serious harm. In this activity, you'll explore how a surrounding ocean of air harbors a microbe population that may be cultured on a moist, nutrient-rich surface.

MATERIALS

- ☐ bread
- ☐ 3 sterile petri dishes (with covers)
- ☐ cotton-tipped applicator
- ☐ distilled water
- ☐ clear tape
- ☐ microscope

SEE PAGE 11

Marine biologist **Garriet Smith** of the University of South Carolina answers your questions online.
www.pbs.org/saf/paradise.html

PROCEDURE

1. Moisten three pieces of bread with distilled water. Place each piece in the bottom half of a sterile petri dish. *Do not cover these dishes.*
2. Place one open dish in a hidden location in the school cafeteria. Make sure that the dish is secure and will not be handled. Keep the dish exposed for a two-hour period (include lunch time).
3. Place another open dish in a shady spot outside of the building, away from ants. Again, make sure that you select a protected location. Keep the dish exposed for the same two-hour period.
4. Wet one end of a cotton-tipped applicator with distilled water. Run this moist end along several tabletops. Then, run the tip in a zigzag pattern over the last piece of moistened bread. Cover this dish and seal it closed with clear tape.
5. After two hours, cover and seal the two exposed dishes with tape. Set all three covered dishes in a dark closet or drawer.
6. Each day for one week, examine the appearance of the bread. *Do not open the dishes.* Record any changes in the bread's appearance. Note the numbers, colors and characteristics of any 'splotches' or 'fuzz' patches that appear within the dish. Use your microscope to examine these microbe colonies. Draw what you see.
7. At the week's end, your instructor will collect the dishes and dispose of them.

QUESTIONS

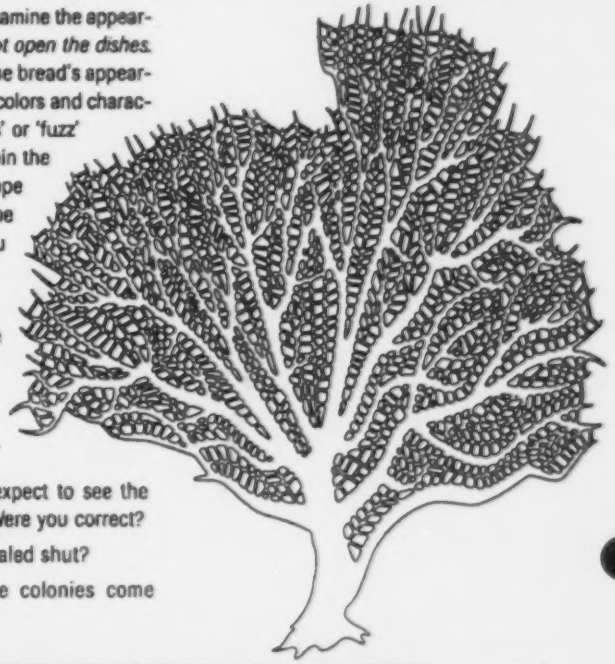
1. In which dish did you expect to see the most microbe growth? Were you correct?
2. Why were the dishes sealed shut?
3. Where did the microbe colonies come from?
4. Why did you use distilled water instead of tap water?
5. What did this experiment tell you about microbes in the air?

EXTENSIONS

1. Is water critical to microbe growth? You be the judge. Design an experiment using raw oatmeal flakes, bread mold (handled by your instructor) and distilled water. You'll also need two petri dishes: one will contain moistened oatmeal flakes; the other will be dry. Inoculate both with bread mold. What happens?
2. Research the story of Sir Alexander Fleming's discovery of penicillin in 1928.
3. Why are coral reefs called the 'rain forests of the ocean'? For more about threats to coral reefs, visit:

www.coral.org/Threats.html

ANSWERS: 2. To investigate why potentially dangerous microbes in the natural environment. 3. Spores that dispersed in air & bio water may be contaminated with microbes or spores.



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ASK THE Scientists Online

Explore Science in Paradise with FRONTIERS Online!

After **Science in Paradise** airs, specialists from the show will answer questions about their work. The scientists featured below will be available from October 7 to 23, 1998. To participate in Ask the Scientists, visit FRONTIERS online at www.pbs.org/saf/.

TURTLE TRAVELS

Zandy Hillis-Starr, a biologist with the National Park Service at Buck Island, tells you more about the successful conservation of hawksbill turtles.

PARADISE POSTPONED

Rick Herd gives you a firsthand report directly from the Montserrat Volcano Observatory.

THE PAN MAN

Learn more about making steel pans from Clement Imbert, a professor of engineering at the University of the West Indies.

BIG DISH

Jim Cordes of Cornell University's Department of Astronomy answers your questions about the world's premier radio telescope.

DUST BUSTING

Garriet Smith, a marine biologist at University of South Carolina, has solved a mystery. Find out how his work may help save the world's coral reefs.

HOW TO "ASK THE SCIENTISTS"

Visit SCIENTIFIC AMERICAN FRONTIERS on PBS Online at www.pbs.org/saf/. Click on "Ask the Scientists" to send your question(s). Scientists' answers will be posted online for FRONTIERS viewers to read.

Remember to e-mail your questions by October 23, 1998!

PBS online

NOTE: AVAILABILITY OF SCIENTISTS IS SUBJECT TO CHANGE.

Selected Web Sites for Show 901

Visit these sites to learn more about topics on **Science in Paradise**. You can find more links to related sites online at www.pbs.org/saf/.

Turtle Travels

kingfish.ssp.nmfs.gov/tmcintyr/turtles/turtle.html

All about sea turtles and recovery plans for endangered species.

www.xmission.com/~gastown/herpmed/chelonia.htm

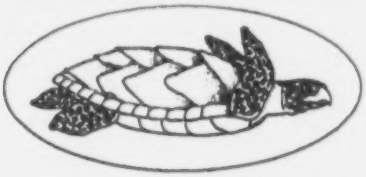
Informational library about turtles, sea turtles and tortoises.

www.cccturtle.org

A Caribbean conservation and sea turtle survival group. Habitats, research programs, notes from the field, satellite tracking, photos, educational resources.

www.cr.nps.gov/parklists/vi.html

Map and virtual view of Buck Island Reef.



Paradise Postponed

www.geo.mtu.edu/volcanoes/west.indies/soufriere/govt/

Montserrat Volcano Observatory. Daily updates and scientific reports of Soufriere Hills Volcano. Maps, chronology, photos, satellite images.

sel.org/montserrat.html

Overview of volcano and recent eruptions.

24.3.19.68/pub/innanen/montserrat

Bill's Montserrat page. Photos, maps of pyroclastic flow and volcanic risks, E-postcards, satellite images, videos, stamps.

The Pan Man

www.smus.se/musikmuseet/pan/

Steel bands. History and photos of steel pans. Play notes on a virtual steel pan.

www.smus.se/musikmuseet/pan/tuning/

Handbook for making and tuning steel pans. Acoustic theory, tools, supplies.

Big Dish

aosun.naic.edu/

Arecibo Observatory. Photos, picture gallery, news, research areas.

www.naic.edu/~nolan/radar/

Arecibo planetary radar. History and goals of radio astronomy and the upgrade. Radar images of asteroids.

www.eecs.wsu.edu/~hudson/

Scott Hudson's pages about Earth-crossing asteroids and a "virtual astronaut." Images and models of asteroids.

www.hawastsoc.org/solar/eng/asteroid.htm

All you ever wanted to know about asteroid exploration. Illustrations, images and animations of many asteroids, the Asteroid Belt and the solar system.

impact.arc.nasa.gov/index.html

Asteroid and Comet Impact Hazards, including statement about Asteroid 1997 XF11.

Dust Busting

www.coral.org/Home.html

Photo gallery and threats to coral reefs around the world. Coral reef conservation.

www.coral.org/IYOR/IYORhome.html

International Year of the Reef, 1997.

www.yoto98.noaa.gov

Year of the Ocean 1998.

volcanoes.usgs.gov

The U.S. Geological Survey Volcano Hazards program monitors active volcanoes in the U.S.

At press time, the online features and sites listed here were current. Due to the rapidly changing online world, some may have changed or may no longer be available. We recommend that you preview sites before passing them on to students.

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SCIENTIFIC AMERICAN FRONTIERS

Watch It On PBS

SCIENTIFIC AMERICAN FRONTIERS airs on PBS with five new programs each season, October through April. Each hour-long special includes a variety of intriguing science stories based on a single theme.

THIS ISSUE **SHOW 901: Science in Paradise**

***INTERNATIONAL SPECIAL!* WEDNESDAY, OCTOBER 7, 1998**

Dive into the beautiful waters of the Caribbean and find out what scientists are learning about the science of paradise, from underwater coral reefs to asteroids in outer space and a devastating volcano here on Earth.

SHOW 902: Journey to Mars

WEDNESDAY, NOVEMBER 11, 1998

3 . . . 2 . . . 1 . . . Blast off to Mars! Sometime early in the next century, humans may take off on the first manned mission to the Red Planet. Learn about scientists' many new projects, from inflatable habitats to the search for Martian life.

SHOW 903: Animal Einsteins

WEDNESDAY, JANUARY 20, 1999

Dr. Dolittle isn't the only person who talks to the animals. Scientists tell us we can learn much from these furry, feathered and finned creatures. Find out what the latest studies reveal about birds, sea lions, chimps and tamarins.

SHOW 904: Life's Little Questions

WEDNESDAY, FEBRUARY 24, 1999

What makes hot peppers hot? Why do traffic jams happen? What's the best way to combat jet lag? Join host Alan Alda in a scientific quest to answer life's little questions.

SHOW 905: Spiders

WEDNESDAY, APRIL 14, 1999

Meet just a few of the 39,000 known spider species — including the world's largest, a 10-inch tarantula, and a cyberspider that lives inside a computer. And, learn about a 20th-century solution to an ancient fear, arachnophobia.

Great news! SCIENTIFIC AMERICAN FRONTIERS has been named the recipient of a 1998 Parents' Choice Gold Seal Award. Join us for a brand-new season of FRONTIERS — starting with this episode's look at science in the Caribbean.

SEE IT ON PBS

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Requested Teaching Materials for
SCIENCE IN PARADISE
AIR DATE:
October 7, 1998

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TEACHING GUIDE FOR SHOW 902
NOVEMBER 11, 1998 • 8-9 P.M.

Free Poster Inside for DESTINATION: GALAPAGOS ISLANDS
CYBER FIELD TRIP with FRONTIERS! Dec. 8-13, 1998

Journey to Mars

Getting There . . . and Back

A PBS SPECIAL

Hosted by Alan Alda

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SCIENTIFIC AMERICAN FRONTIERS

Show 902: Journey to Mars

November 11, 1998 • 8 p.m. on PBS (CHECK LOCAL LISTINGS)

PATHFINDER AIRBAGS: This artist's rendering shows Pathfinder's final descent through the Martian atmosphere just minutes before it comes to a complete halt on the Martian surface. The spacecraft is enclosed in a huge cocoon of airbags, which has just been cut from its parachute. The spacecraft, protected inside the airbags, will bounce as high as a five-story building before stopping. Once it is stationary, motion detectors on-board the spacecraft will sense the lack of movement and trigger a mechanism that will deflate and retract the airbags.

Painting by Pat Rawlings, SAIC, courtesy NASA/JPL/Caltech.
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ON THE COVER: Mars, the red planet.

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5 OUT OF THIN AIR
Robert Zubrin's Mars mission uses the Martian atmosphere to make fuel for the trip home.
ACTIVITIES: Chemistry on Mars; simple electrolysis
RUNNING TIME: 8:50

6 NASA'S WAY TO MARS
An inflatable habitat exemplifies NASA's new thinking about interplanetary exploration.
ACTIVITY: Make a Mars lander
RUNNING TIME: 9:35

7 WHY GO TO MARS?
A rock that left Mars 16 million years ago may contain clues about ancient life on the planet.
ACTIVITY: Seeing Mars in three dimensions
RUNNING TIME: 8:29

8 WE'RE ON OUR WAY
The six-month journey to Mars would require major adaptations from space travelers.
ACTIVITY: Martian challenges
RUNNING TIME: 11:02

9 HOUSTON, WE'VE HAD A PROBLEM!
Virtual reality technology could help astronauts practice making repairs to their spacecraft.
ACTIVITY: Build and test a Mars rover
RUNNING TIME: 4:00

10 GETTING THERE
Alan Alda braves the human-rated centrifuge to test how motor skills work in changing gravity.
ACTIVITY: Design and probe a shoebox planet
RUNNING TIME: 8:08

Plus, in every issue . . .

4 VIEWER CHALLENGE
Guided viewing quiz questions, T-shirt prizes!

11 FRONTIERS ONLINE
Visit us at www.pbs.org/saf/

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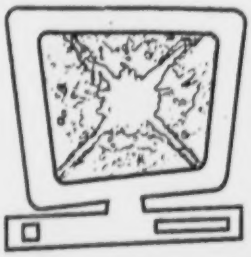

Looking for current or past episodes of SCIENTIFIC AMERICAN FRONTIERS on your local public television station? We've made it easy for you! The FRONTIERS website now features a comprehensive listing of FRONTIERS programs airing across the country. You can search by city or show to find the program or station you're looking for! Go to www.pbs.org/saf/ and click "Schedule."

You'll find fascinating articles in each issue of Scientific American magazine, with multiple links to episodes of FRONTIERS. To subscribe, write to:
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CURRICULUM LINKS ➔ NATIONAL SCIENCE EDUCATION STANDARDS

CHEMISTRY: reactions
EARTH SCIENCE: astronomy, solar system
HISTORY: exploration, moon landing, U.S.
TECHNOLOGY: engineering, inventions

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8: Properties and Changes of Properties in Matter; **9-12:** Chemical Reactions / **EARTH AND SPACE SCIENCE: 5-8:** Earth in the Solar System; **9-12:** Origin and Evolution of the Universe / **SCIENCE & TECHNOLOGY: 5-8, 9-12:** Understandings about Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Natural Resources / **HISTORY AND NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor; **9-12:** Historical Perspectives

CURRICULUM LINKS ➔ NATIONAL SCIENCE EDUCATION STANDARDS

EARTH SCIENCE: asteroids, astronomy, meteors, solar system
PHYSICAL SCIENCE: drag, materials, velocity
TECHNOLOGY: engineering, space flights

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8, 9-12: Motions and Forces / **EARTH AND SPACE SCIENCE: 5-8:** Earth in the Solar System; **9-12:** Origin and Evolution of the Universe / **SCIENCE & TECHNOLOGY: 5-8, 9-12:** Abilities of Technological Design / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Natural Hazards, Risks and Benefits, Science and Technology in Society; **9-12:** Natural Resources / **HISTORY AND NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor; **9-12:** Historical Perspectives

CURRICULUM LINKS ➔ NATIONAL SCIENCE EDUCATION STANDARDS

EARTH SCIENCE: extreme environments, geology, minerals, structure of universe
LIFE SCIENCE: bacteria, evolution, fossils
LITERATURE: science fiction
TECHNOLOGY: computer graphics

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8: Properties and Changes of Properties in Matter; **9-12:** Structure and Properties of Matter / **LIFE SCIENCE: 5-8:** Diversity and Adaptations of Organisms; **9-12:** Biological Evolution / **EARTH AND SPACE SCIENCE: 5-8:** Structure of the Earth System; **9-12:** Geochemical Cycles, Origin and Evolution of the Earth System / **HISTORY AND NATURE OF SCIENCE: 5-8:** History of Science; **9-12:** Nature of Scientific Knowledge, Historical Perspectives

CURRICULUM LINKS ➔ NATIONAL SCIENCE EDUCATION STANDARDS

BIOLOGY/LIFE SCIENCE: carbon cycle, human physiology
EARTH SCIENCE: ecosystems, space flight
PHYSICAL SCIENCE: microgravity
PSYCHOLOGY: risk assessment

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8, 9-12: Motions and Forces / **LIFE SCIENCE: 5-8:** Populations and Ecosystems, Diversity and Adaptations of Organisms; **9-12:** Behavior of Organisms / **SCIENCE & TECHNOLOGY: 5-8, 9-12:** Abilities of Technological Design / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Populations, Resources and Environments; **9-12:** Natural Resources / **HISTORY AND NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor; **9-12:** Nature of Scientific Knowledge

CURRICULUM LINKS ➔ NATIONAL SCIENCE EDUCATION STANDARDS

EARTH SCIENCE: space flight
PSYCHOLOGY
TECHNOLOGY: virtual reality

SCIENCE AS INQUIRY / SCIENCE & TECHNOLOGY: 5-8, 9-12: Abilities of Technological Design, Understandings about Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Risks and Benefits; **9-12:** Natural and Human-induced Hazards / **HISTORY AND NATURE OF SCIENCE: 5-8, 9-12:** Science as a Human Endeavor

CURRICULUM LINKS ➔ NATIONAL SCIENCE EDUCATION STANDARDS

EARTH SCIENCE: space flight
LIFE SCIENCE: nervous system
PHYSICAL SCIENCE: forces, gravity, microgravity

SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8: Diversity and Adaptations of Organisms; **9-12:** Behavior of Organisms / **SCIENCE & TECHNOLOGY: 5-8, 9-12:** Abilities of Technological Design / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Science and Technology in Local, National and Global Challenges / **HISTORY AND NATURE OF SCIENCE: 5-8, 9-12:** Science as a Human Endeavor

FREE TAPING RIGHTS

- ✔ As a teacher, you have free off-air taping rights in perpetuity for classroom use.
- ✔ Always check TV listings to confirm air date and time.
- ✔ If you can't find the show in your TV listings, call your local PBS station.
- ✔ Educators may photocopy all materials in this guide for classroom use.
- ✔ Do you need help? Call the FRONTIERS School Program at 800-315-5010.
- ✔ Videotapes of past shows can be purchased ($21.97 each). Call 800-315-5010.

LET US HEAR FROM YOU!

Do you have a comment or question about FRONTIERS? Do you know someone who wants to sign up for free teaching materials? PLEASE CONTACT US . . .
BY MAIL: SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425 • PHONE: 800-315-5010 • FAX: 215-579-8589 • E-MAIL: saf@pbs.org

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VIEWER CHALLENGE

Journey to Mars

Show 902 • November 11, 1998, at 8 p.m. on PBS (CHECK LOCAL LISTINGS)
Watch SCIENTIFIC AMERICAN FRONTIERS for answers to the questions on this page.
Answer the 10 questions correctly and you'll be eligible to win a FRONTIERS T-shirt!

SCIENTIFIC AMERICAN FRONTIERS

Reminder: Cover the answer key at the bottom of this page before photocopying.

Student's Name: _____

Teacher's Name & Course: _____

Out of Thin Air

1. Robert Zubrin shows how to make fuel on Mars for the return trip to Earth using the main component in the Martian atmosphere, namely:
   - ☐ a. hydrogen.
   - ☐ b. carbon dioxide.
   - ☐ c. carbon monoxide.
   - ☐ d. oxygen.
2. Zubrin believes we should apply this basic rule to Martian exploration:

   _____

NASA's Way to Mars

3. How long would it take (in NASA's current mission scenario) to travel from Earth to Mars?
   - ☐ a. 6 months
   - ☐ b. 18 months
   - ☐ c. 2 years
   - ☐ d. 26 months
4. In the inflatable habitat, the layers of fabric form a shield that protects the spacecraft from:

   _____

Why Go to Mars?

5. Scientists now believe Mars was once:
   - ☐ a. even colder than it is today.
   - ☐ b. all a desert.
   - ☐ c. covered with dry ice.
   - ☐ d. warm and wet.
6. The rock or meteorite that broke off from Mars 16 million years ago may contain evidence of:

   _____

We're on Our Way

7. Name two effects weightlessness during space travel has on the human body:

   _____

   _____

Houston, We've Had a Problem!

8. This technology could help astronauts make repairs while in space or on Mars:

   _____

Getting There

9. Why do Alan Alda's arms feel heavier when he's in the human centrifuge?

   _____

   _____

10. Slow adaptation to changing gravity makes this one of the most dangerous times for astronauts:
    - ☐ a. takeoff.
    - ☐ b. landing.
    - ☐ c. mid-flight.
    - ☐ d. two days after landing.

Be sure to visit FRONTIERS online for a special **Destination: Galapagos Islands** Cyber Field Trip. You can enter a special Science Scavenger Hunt contest to win a colorful T-shirt designed especially for the FRONTIERS expedition to the Galapagos Islands! The field trip will take place December 6-13, but you don't have to wait to prepare for the contest. Check out the website beginning in mid-October to learn more about the Galapagos Islands. ***Good luck!***

FOR TEACHERS ONLY

When completed, this page can become an entry to the FRONTIERS T-shirt contest; 20 winners (10 students, 10 teachers) will be drawn at random for each show. To enter the T-shirt drawing, send all completed challenges in one envelope with a cover sheet to: Viewer Challenge, SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425. Mail completed entries by **December 11, 1998.**

TIP: You can download these questions on the Web: www.pbs.org/saf/4_class/44_guides/guide_902/4492_challenge.html

IMPORTANT!! Please include a separate cover sheet and tell us:

- number of challenges submitted
- teacher's name
- grade and course
- school name, address and phone number
- where your students watched the show — at home, at school or both
- the name of your students' favorite story in this show (conduct a quick poll to find out)

Thank you!

Answers to the Viewer Challenge: 1. b 2. living off the land or using natural or local resources 3. a 4. a, particle of rock and dust (micrometeroid) or space debris 5. d 6. dissolved Martian microorganisms 7. bone and muscle loss, heart weakness 8. VR or virtual reality 9. centrifugal force feels like extra gravity 10. b

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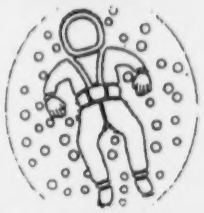
SCIENTIFIC AMERICAN FRONTIERS

OUT OF THIN AIR



Some early explorers on Earth ran into trouble when they did not follow the practice of living off the land. As you see on FRONTIERS, aerospace engineer Robert Zubrin believes interplanetary pioneers should follow the same principle and use the Martian atmosphere to make fuel and other products. Zubrin elaborates his vision and his plans for a Mars mission he calls "Mars Direct."

Chemistry on Mars

Engineer Robert Zubrin has worked out step-by-step plans for a Mars mission at a relatively low cost. One of his basic principles is living off the land and using local resources. On FRONTIERS, Zubrin shows how rocket fuel could be made out of raw materials in the Martian atmosphere.

In the Mars chemical plant, the Sabatier reaction combines carbon dioxide with hydrogen to produce methane (which forms the basis for methanol rocket fuel) and water ($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$).

After water (H_2O) is obtained, it can be separated into its two components, hydrogen and oxygen. Similarly, scientists have proposed that oxygen can be obtained from ice on the moon. In this activity, you will perform a simplified method of aqueous electrolysis to split water into its two chemical elements using electric current from a battery.

MATERIALS

- ☐ 2 pencils sharpened at both ends
- ☐ 1 9-volt battery
- ☐ 15# amp coated fuse wire
- ☐ water in a beaker about 6 cm deep
- ☐ scissors
- ☐ heavy paper
- ☐ waterproof tape

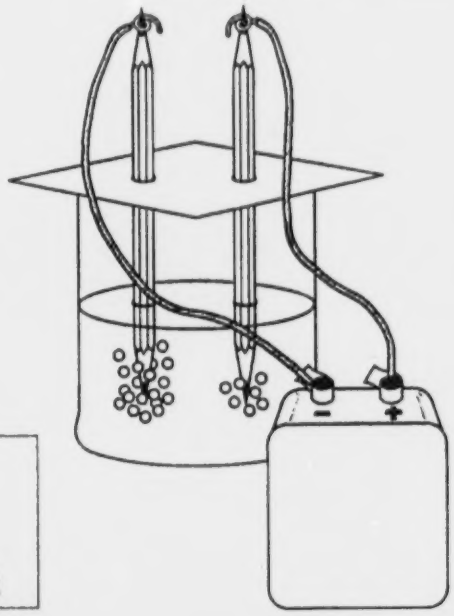
SEE PAGE 11

Aerospace engineer **Robert Zubrin** answers your questions online. **www.pbs.org/saf/mars.html**

PROCEDURE

1. Cut two pieces of fuse wire about 20 cm each. Remove about one inch of coating from each end of each wire. Make a loop at one end of each wire that fits around the point of a pencil.
2. Place a square of paper on top of the beaker of water. Push the pencils through it so they rest with their points in the water. Place the wire loops around the pencil points sticking out of the water.
3. Wind the free end of one wire around the positive terminal of the battery and tape to secure; wind the free end of the other wire around the negative terminal and secure.

   SAFETY PRECAUTION: When the wires are attached to the battery terminals, they are electrically "live." Be careful not to allow exposed wires to touch each other while live – the battery could overheat or explode.
4. Watch the pencil points in the water. What happens? Bubbles of oxygen and hydrogen should form around the pencil points.



5. How do you know which bubbles are oxygen and hydrogen? Observe the battery terminals. Oxygen collects around the pencil attached to the positive terminal (+). Hydrogen collects around the pencil attached to the negative terminal (-). Explore why this happens. Which pencil do you think will have the most bubbles around it and why?

In Zubrin's plan, oxygen is stored as rocket propellant, and the hydrogen is recycled back into the chemical plant to make more methane and water. The methanol would also be used by Mars rovers as fuel. Zubrin also has a plan for making ethylene (C_2H_4) — another fuel and the basis of plastics — out of carbon dioxide and hydrogen.

What Do We Know About Mars?

- ☐ Pathfinder and other Mars missions have given us much information about the red planet. The planet appears red because a fine, iron-rich dust covers most of the surface.
- ☐ The Martian day is very similar to ours: 24 hours and 7 minutes. The planet rotates on an axis with a 24-degree tilt. Compare to Earth's day and orbit.
- ☐ The carbon-rich atmosphere on Mars is about 1% as thick as Earth's atmosphere. The "thin air" of Mars consists of 95% carbon dioxide and 3% nitrogen, with traces of oxygen, argon, carbon monoxide and water. Compare this chemical composition with the Earth's atmosphere.
- ☐ Mars is believed to have been much warmer and wetter in its distant past, with a much thicker layer of CO_2, or a "greenhouse effect." Water today is frozen as permafrost in the soil and in the southern polar cap as dry ice. What scientists learn about how Mars's climate changed could help us understand Earth's climate.

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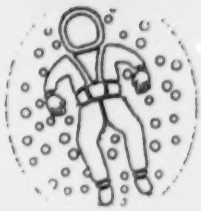
SCIENTIFIC AMERICAN FRONTIERS

NASA'S WAY TO MARS

Space travel is hazardous. On this episode of FRONTIERS, NASA engineers demonstrate how a tiny particle can punch a giant hole in a space ship. NASA's new way of thinking includes an inflatable space habitat, the Transhab, which uses layered fabric walls. The wall is tested to see what happens when it's bombarded by space debris. Will fabric layers protect astronauts? Find out on the show.



Make a Mars Lander

Imagine a bouncing spacecraft coming to rest on an alien planet. Giant balloons that surround the rocket deflate and out rolls a robotic vehicle. This may sound like science fiction, but it's science fact. The Mars lander Pathfinder was launched in December 1996 and entered the Martian atmosphere in July 1997. The lander deployed a parachute to slow down. Inflated air bags protected the lander as it bounced more than 15 times. (You can see an artist's rendering of Pathfinder's protective airbags on page 2 of this guide.) NASA's radical "faster, cheaper, better" design and the success of Pathfinder launched a new era of space exploration.

Can you build a bouncing lander? Take the challenge and find out. In this activity, you'll design, construct and test an original model. Hold a contest to see which landers work best to keep your cargo from breaking.

MATERIALS

- ☐ raw eggs
- ☐ markers
- ☐ tape
- ☐ packing "peanuts"
- ☐ chenille stems (pipe cleaners)
- ☐ balloons (various sizes)

NOTE: You may wish to replace eggs with water-filled balloons or use plastic eggs for a practice round.

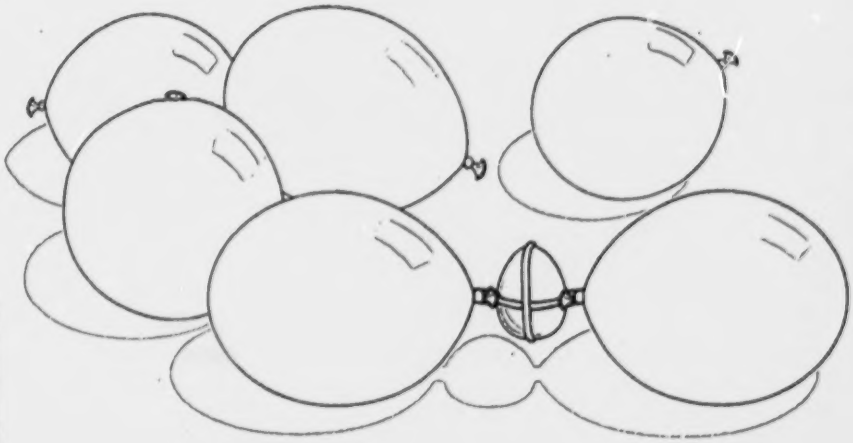
PROCEDURE

1. Use chenille stems to construct a harness around an egg.
2. Work with a partner or in teams to make your basic bouncer. Discuss the best way to cushion an egg's fall using two or more air-filled balloon bumpers.
3. Blow up the balloons and fasten them to the harness with tape so they surround the egg with a cushion.
4. Drop the "lander" several times from a height of three feet. Observe the orientation of the egg when the lander comes to rest.
5. *This side up!* Use the marker to place an "X" on the top of the narrow egg dome. Redesign the lander so that when it comes to rest, the "X" always faces upwards. Use extra balloons, packing peanuts and chenille stems as needed.

EXTENSIONS

1. Some critics of space exploration say it's too expensive. Assign "costs" to materials used to make your lander. For example, each chenille stem costs $100; eggs cost $200; balloons, $500 (count the ones that break, too). How much does each lander cost? Which lander is successful *and* comes in at the lowest cost?
2. Engineer Robert Zubrin describes his Mars hab as a "tuna can." Each hab is 8 meters (less than 30 feet) in diameter. In the gym or outside, use string or chalk to measure and draw a circle the size of the hab. Compare the dimensions to other structures, like a car or tent. Talk about what it might be like for four people to spend six months living in the hab.
3. One of the concerns about a trip to Mars is bombardment by high-speed space particles that could damage or even rupture the ship's hull. The particles tested on FRONTIERS each have a mass of about 1.5g. One piece of M&M candy has a mass of 1g. Can your lander survive a shower of M&M particles? What happens to the space vehicle as the particles become larger? Consider the tradeoffs (heavier protective shield, more weight, higher costs; lighter shield, less protection, lower costs).
4. Thousands of images from the Pathfinder mission are archived on the Internet, along with details on the mission, scientific results, instruments and more:

   mars.jpl.nasa.gov/index0.html



SEE PAGE 11

Donna Fender
of NASA's Transhab Project
answers your questions online.
www.pbs.org/saf/mars.html

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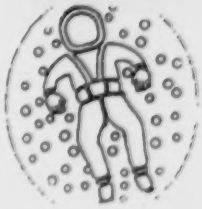
SCIENTIFIC AMERICAN FRONTIERS

WHY GO TO MARS?



A four-pound rock that left Mars 16 million years ago may hold the clues to ancient life on the planet. The rock is one of 13 Mars meteorites found on Earth. These rocks may contain clues to the ancient history of planet Mars, believed to have been a warmer, wetter place over 3 billion years ago. NASA's planetary scientists tell us why they think the Mars rock contains evidence of ancient life.

3-D Mars

Scientists studying Mars today enjoy many technological advances early astronomers did not have. One technique, 3-D imaging, was critical to the 1997 Pathfinder mission. A digital stereoscopic camera on the Sojourner rover took pictures of the Martian surface that were coded into radio signals and beamed back to Earth. Ground controllers navigated the rover across the surface using 3-D technology.

One way to view an image in 3-D is to make an anaglyph. Two images of the same subject are used — one image is tinted red and the other is tinted blue or green. These colored images are stacked upon each other. When you view an anaglyph through red/blue glasses, the red lens cancels out the red image and the blue lens cancels out the blue image. This allows each eye to see a slightly different view, and you brain interprets a 3-D image. In this activity, make a pair of 3-D glasses and use them to view Mars images on the Internet.

MATERIALS

- ☐ scissors ☐ tape
- ☐ heavy stock paper
- ☐ transparent red plastic
- ☐ transparent blue plastic
- ☐ 3-D comic strips or other images (e.g., Internet sites listed in activity)

NOTE: Use plastic report covers or lens gels used by theater departments for the plastic sheets.

SEE PAGE 11

Biologist **Kathie Thomas-Keprta** of NASA's Mars meteorite group answers your questions online. **www.pbs.org/saf/mars.html**

PROCEDURE

1. To make 3-D glasses, enlarge the image at right by 185% (you may need to make this percentage smaller or larger to fit your head and eyes properly). Trace the image onto heavy stock paper and cut out the eye holes.
2. Cut out one rectangle each of red and blue plastic, both about the size of a 35 mm slide. Tape one rectangle over each eye window in the glasses, and use your viewers to examine 3-D comics or other images. Can you tell how the distance between red and blue lines affects the apparent depth of the image? (The closer the lines, the further the apparent image.)
3. Check out these sites for 3-D images of Mars. Or do your own Internet search using keywords like "Mars," "3-D," "anaglyph" and "Pathfinder":

   www.rainbowsymphony.com/marsglry.html

   www.doe.state.in.us/space/3DSpaceImages.html

   See fantastic 3-D color images and find out where to get 3-D glasses:

   mars.jpl.nasa.gov/index1.html

   The August 1998 issue of *National Geographic* features an article about Mars and includes 3-D images of the planet (and free 3-D glasses). You can find even more 3-D Mars images in the new book *Mars: Uncovering the Secrets of the Red Planet.*

EXTENSIONS

1. The Mars rock seen on FRONTIERS was broken off from Mars 16 million years ago, and traveled around in space until 13,000 years ago, when it landed in Antarctica. Look for news reports of other discoveries of Mars meteorites.
2. SCIENTIFIC AMERICAN FRONTIERS first met exobiologist Jack Farmer on **Life's Big Questions** (Show 501) in "Are We Alone?" You can read about Farmer's life and microfossil discoveries in his field journal:

   quest.arc.nasa.gov/mars/team/farmer.html

3. Scientists have found evidence of microbes living in extreme environments on Earth, far beneath the surface of the planet and at ocean thermal vents (where microbes survive without sunlight), even in the Antarctic and in Yellowstone's hot springs (some of these microbes are believed to be primitive bacteria called Archaea). What do these findings suggest about the possibility of life on Mars?
4. Debate the pros and cons of sending robots vs. people to Mars. The late scientist Carl Sagan, an early proponent of Mars exploration, argued for robotic explorations. Find out more about his reasoning. Do you agree or disagree with him?

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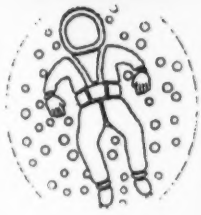
SCIENTIFIC AMERICAN FRONTIERS

WE'RE ON OUR WAY

While living at zero Gs may seem appealing, the toll on the human body can be significant. In a weightless environment, bones, muscles, even the heart can deteriorate. Engineers invent and test experimental exercise equipment to keep astronauts fit. Watch as Alan Alda finds out that it's not quite like the gym at home! Then, meet some human volunteers living in a simulated space habitat.



Martian Challenges

As you observe on FRONTIERS, interplanetary explorers will face many challenges on their journeys. Watch FRONTIERS, then try these mini-activities about topics on the show to learn more about Mars.

Extended periods of weightlessness require significant adaptations in all areas of life, from exercise to growing food. Life at zero Gs affects the body "from bones to brain," according to *Scientific American*, including motion sickness, head congestion, muscle weakness and atrophy, bone loss and more, as you see on FRONTIERS. For more information, read "Weightlessness and the Human Body" in the September 1998 issue of *Scientific American*.

After watching FRONTIERS, brainstorm a new type of ***exercise equipment for use in space***. Draw a model of your new equipment. What modifications do you need to make to be sure the user stays on the equipment without the help of gravity?

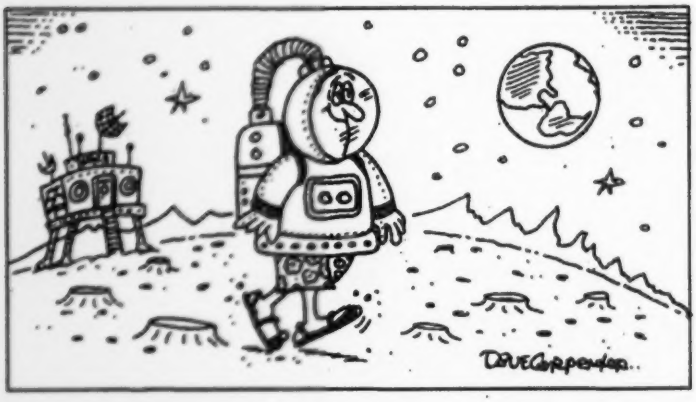
How might ***caloric and nutritional needs*** be met on a long space flight? Currently, astronauts are limited to less than four pounds of food a day, plus another pound for packaging. Calculate the weight of food products for six months of typical meals, and you'll understand why astronauts on long missions would have to rely on recycling and foods grown in the spacecraft. How would you select and package foods for a space mission? Create new menus for space travel.

When it's closest to Earth, Mars is within 60 million km; at its farthest, 400 million km. Draw pictures or make models of the orbits.

Watch the discussions of ***life support systems*** on the show. Then brainstorm applications of the life support concept that could be used here on Earth; for example, watering a garden with wash water or irrigating a golf course with treated effluent.

A compass will not work on Mars because a magnetic field is practically non-existent. How would you navigate a rover?

Martian gravity is 38% of Earth's. If you weigh 100 pounds on Earth, how much would you weigh on Mars?



Temperatures on Mars fluctuate wildly.

For reasons science does not completely understand, the temperature drops dramatically only a few feet above the surface of Mars in the daytime. If you stood on the surface, your feet would be warmer than your head in the daytime.

Typical daytime temperatures at the surface range between -50°C and 10°C, but can go as high as 18°C, and drop as low as -90°C at night. At five feet above the surface, temperatures range between a daytime high of about -9°C and a nighttime low of -76°C. Set up a table and convert these temperatures to Fahrenheit, using the following formula: $°F = (°C \times 1.8) + 32$.

What would your feet feel like at Mars's surface temperature? How much colder would your head feel?

SEE PAGE 11

Astronaut **Andrew Thomas** answers your questions online.
www.pbs.org/saf/mars.html

FIND OUT MORE . . .

- ☐ Some scientists think we should terraform Mars – make it more Earthlike by changing the atmosphere to one that's more like our own, so we could inhabit the planet. Do you agree? How would the Martian atmosphere need to change?
- ☐ Many more details about Mars can be found on the Web (see p. 11 for suggested sites), in issues of *Scientific American* and in Robert Zubrin's book, *The Case for Mars: The Plan to Settle the Red Planet and Why We Must* (1996, Touchstone), including a chapter on how to terraform Mars.
- ☐ **More from Mir:** In 1998, Alan Alda interviewed astronaut Andy Thomas in a live Webcast between Earth and Mir. Hear more of this interview or read the transcript at:
  www.pbs.org/saf/mirtomars/

You can also read more about Mars, Mir and space exploration, and find links to cool websites.

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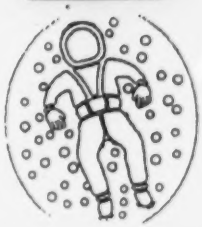
SCIENTIFIC AMERICAN FRONTIERS

HOUSTON, WE'VE HAD A PROBLEM!



Things go wrong in space. Astronauts survived the ill-fated Apollo 13 mission when the spacecraft lost power. Cosmonauts on the aging Mir have dealt with all kinds of problems, from fire to a collision. Today's virtual reality technology may help future astronauts fix problems en route to Mars.

Build a Martian Rover

On July 5, 1997, the day after the Pathfinder landed on the surface of Mars, its protective airbags retracted and the Sojourner rover rolled down the ramp of the lander and out onto the Martian surface.

Sojourner was dubbed the "little rover that could." Until the end of September 1997, when wild temperature fluctuations on Mars caused it to stop transmitting data, the Sojourner explored a small area on the planet's surface. Its instruments analyzed soil and rocks, sending back images and data from the red planet.

Future Mars missions will also include rovers, which will be doing much of the work until humans are able to explore the planet. NASA's next scheduled mission is Mars Surveyor 98, set to launch in December 1998.

Here's your chance to build a rover vehicle and test your remote driving abilities by observing its surroundings through a monitor display.

MATERIALS

- ☐ large remote-controlled, wheeled toy vehicle
- ☐ digital video camera (like the one shown here) or a regular camcorder
- ☐ long video connecting cable
- ☐ monitor
- ☐ tape
- ☐ magnet
- ☐ cardboard
- ☐ nails
- ☐ washers

SEE PAGE 11

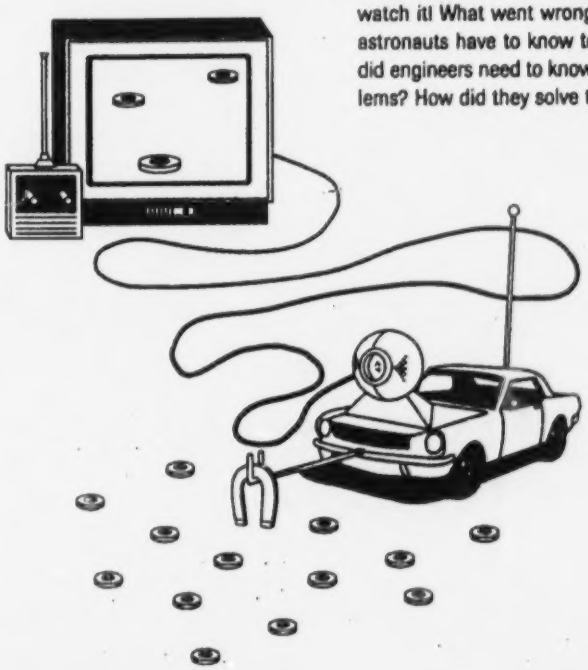
Scientist **Tim Salto** of the Virtual Environment Technology Lab at University of Houston answers your questions online.
www.pbs.org/saf/mars.html

PROCEDURE

1. Use tape to secure the camera to the chassis of the remote-controlled vehicle. (You may wish to use Legos, solar cells or other materials to build simpler rovers. Check out the new computerized rover kit from Lego, too.)
2. Use a long video cable to attach the camera output to the monitor input.
3. Construct a "magnetic snare" and secure it to the vehicle. The snare will be used to pick up "surface samples" (washers and nails).

CHALLENGE

1. Scatter magnetic targets on the floor of a flat room. Place the rover in one corner of this "alien landscape." Carefully run the video connecting cable from the vehicle to the monitor, in an adjoining room.
2. The pilot sits in the adjoining room and watches the monitor display. Using only televised feedback, the pilot must use the rover to collect magnetic targets within a fixed period of time.



EXTENSIONS

1. Search the Web for other ideas on building Mars rovers. You can find out much more about the Sojourner rover at:

   mars.jpl.nasa.gov/mpf/rover.html

   Learn more about NASA's plans to send an orbiter and a lander with rover to Mars in 2001:

   mars.jpl.nasa.gov/2001/rover/rover_home.html
2. Virtual reality (VR) is being used for a variety of earthly applications, including behavioral therapy. Watch "Virtual Fear" in **21st Century Medicine** (Show 605) to see how VR is helping people overcome their fear of heights. And tune in for **Spiders!** (April 14, 1999) to see how virtual reality is helping people with arachnophobia.
3. If you haven't seen the movie *Apollo 13*, watch it! What went wrong? What did the astronauts have to know to survive? What did engineers need to know to fix the problems? How did they solve the problems?

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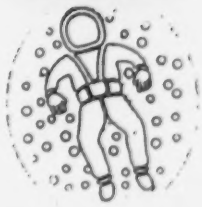
GETTING THERE

Space travelers heading to or from Mars would be weightless for a long time and need to adapt quickly to gravity upon landing at their destination. To find out what happens to motor skills in changing gravity, Alan Alda braves the human-rated centrifuge. Viewers will also get a preview of the latest designs in space suits during a simulated microfossil hunt in the Arizona Desert.



Shoebox Planet

Until recently, Earthlings could only observe Mars from a great distance. Telescopes, the Mariner and Viking missions and, recently, Pathfinder have brought the planet closer to us. Despite the thousands of images we have of Mars, we still have only snapshots and not the complete picture of the planet's surface. The ultimate dream of many scientists is for a human to reach the planet itself and explore it.

Until people land on Mars, science has to rely on probes and pictures for planetary exploration. In this activity, you'll design and use probes to discover features of an unknown planet's surface and compare the probe's accuracy with human observation. Work in groups of two or more.

MATERIALS

- ☐ shoe boxes with lids (1 box per group of students)
- ☐ various materials for constructing planet's surface and surface features (e.g., clay, crumpled paper, cotton, baby powder, fabric, ice, soil, water, lemon juice, "slime," etc.)
- ☐ examples of probes that might be used to sample surface (e.g., litmus paper, lab thermometer, wires, straws)

PROCEDURE

PART 1: DESIGNING THE PLANET

Draw a grid on the top of the box and punch a hole the size of a pencil in the middle of each space on the grid (see FIGURE 1). Your class should agree on a set size for the spaces in the grid.

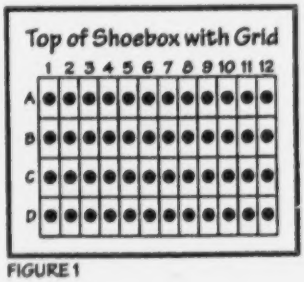
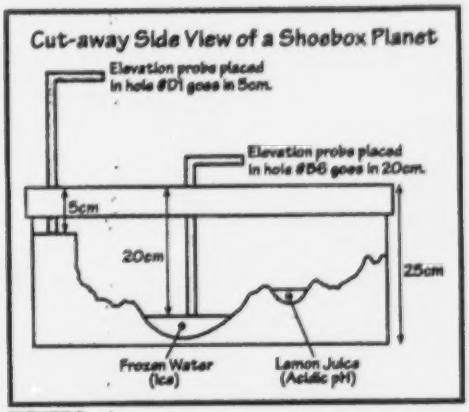


FIGURE 1


Cut-away Side View of a Shoebox Planet
Elevation probe placed in hole #D1 goes in 5cm.
Elevation probe placed in hole #B6 goes in 20cm.
5cm
20cm
25cm
Frozen Water (Ice)
Lemon Juice (Acidic pH)
FIGURE 2

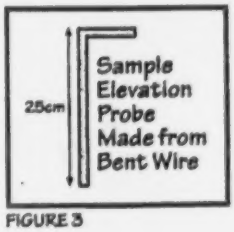


FIGURE 3

Sample Probe Data Chart

Data from Elevation Probe	
LOCATION	DEPTH (25cm – insertion)
D1	25 – 5 = 20cm
B6	25 – 20 = 5cm

FIGURE 4

Design a planet surface with varied features (see FIGURE 2). As a class, brainstorm different features you might incorporate into your designs. Then work with a partner to create your planet inside your shoebox. Vary surface features by including different heights, textures, densities, liquids with different pH's, etc. Keep designs secret from classmates until after exploration.

PART 2: DESIGNING PROBES

Design a series of probes to be used to explore another team's planet (see FIGURE 3). Each probe can be used more than once, but the planet can be probed no more than a total of 30 times.

PART 3: IMAGING THE PLANET

1. Launch probes by inserting them through the holes in the grid of another team's planet to the surface.
2. Collect data and record results (see FIGURE 4). In the first round of exploration, teams should probe the surface ten times.
3. When ten probes of the surface are complete, prepare a brief preliminary report that includes a description of features, as well as a simple drawing of the surface. Adjust your exploration plan based on the data you've already collected.
4. Now, using the preliminary data and report, probe the planet 20 more times and record results.
5. Prepare a final report and surface drawing based on your additional probes.
6. Take off the lid and compare the report to the actual surface of the planet.

QUESTIONS

1. How does the picture of the planet defined by your probes compare to reality?
2. What are the advantages and disadvantages of sending people to investigate a planet, rather than probes or robots?

SEE PAGE 11

NASA Ames Research Center psychologist **Malcolm Cohen** answers your questions online. **www.pbs.org/saf/mars.html**

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Selected Websites for Show 902

Visit these sites to learn more about topics on **Journey to Mars**. You can find more links to related sites online at www.pbs.org/saf/.

Mars Exploration and Mars Missions

www.reston.com/astro/mars/catalog.html
The Whole Mars Catalog has information on just about any Mars-related topic you can think of.

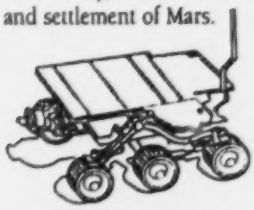
seds.lpl.arizona.edu/nineplanets/nineplanets/mars.html
From mythology to music to missions. Created by Students for the Exploration and Development of Space (SEDS).

www.seds.org/~spider/mars/mars.html
Information about the planet, Mars missions and future exploration. Photos too.

mars.excite.com/mars/nav.html
Links to all the Mars missions.

cmex-www.arc.nasa.gov
Ames Center for Mars Exploration.

www.marssociety.org
The Mars Society, dedicated to the exploration and settlement of Mars.



pds.jpl.nasa.gov/planets/welcome/mars.htm
Statistical details about Mars, plus images and descriptions of major topographical features.

nova.stanford.edu/projects/mgs/dmwr.html
The Daily Martian Weather Report from the Mars Global Surveyor Radio Science Team.

www.nw.net/mars/marsdirect.html
Robert Zubrin's Mars Direct plan.

Space Links for Students

www.sciam.com/specialissues/0398cosmos/0398quicksummary.html
Scientific American's special issue "Magnificent Cosmos" features a fascinating planetary tour of our solar system, and more.

spaceday.com
Celebrate Space Day in May 1999.

www.spacehab.com/sk/index6.html
SpaceKids makes learning about space fun for teachers and students.

www.pbs.org/deepspace/classroom/activity7.html
"Is There Really Life on Mars?" classroom activity, based on the PBS series "Mysteries of Deep Space."

liftoff.msfc.nasa.gov/kids/Welcome.html
Cyberspace meets outerspace at Kid's Space. Lots of fun.

At press time, the online features and sites listed here were current. Due to the rapidly changing online world, some may have changed or may no longer be available. We recommend that you preview sites before passing them on to students.

From Mir to Mars

In March 1998, FRONTIERS host Alan Alda interviewed NASA astronaut Andy Thomas, who was living on the Russian space station Mir at the time. You see part of this interview on this episode of FRONTIERS – but the entire conversation is available on the FRONTIERS website! You can watch and hear the interview – and learn more about NASA's work on Mir and the possibility of interplanetary travel – at:

www.pbs.org/saf/mirtomars/

Explore Journey to Mars with FRONTIERS Online!

ASK THE Scientists Online

After **Journey to Mars** airs, specialists from the show will answer questions about their work. The scientists featured below will be available from November 11 to 27, 1998. To participate in Ask the Scientists, visit FRONTIERS online at www.pbs.org/saf/.

OUT OF THIN AIR

Aerospace engineer Robert Zubrin has developed a revolutionary plan for going to Mars. Find out how his pioneering research can make a Mars mission affordable.

NASA'S WAY TO MARS

Donna Fender of NASA's Transhab Project answers your questions about inflatable habitats that may be home for astronauts on the surface of Mars.

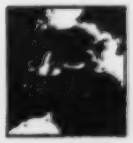
WHY GO TO MARS?

Is there evidence of life on Mars? Biologist Kathie Thomas-Keprta of NASA's Mars meteorite group shares the latest information about this controversial question.

WE'RE ON OUR WAY

On the Mir space station, Andrew Thomas experienced the physical and psychological challenges of life in space. Now this astronaut gives FRONTIERS viewers a first-hand report.

HOUSTON, WE'VE HAD A PROBLEM!



Tim Saito of the Virtual Environment Technology Lab at University of Houston tells you more about how virtual reality can help astronauts troubleshoot systems in space.

GETTING THERE

Ask Malcolm Cohen, a psychologist at NASA Ames Research Center, how his research is helping to solve problems astronauts experience after the weightlessness of space.

HOW TO "ASK THE SCIENTISTS"

Visit SCIENTIFIC AMERICAN FRONTIERS on PBS Online at www.pbs.org/saf/. Click on "Ask the Scientists" to send your question(s). Scientists' answers will be posted online for FRONTIERS viewers to read.

Remember to e-mail your questions by November 27, 1998!

PBS online

NOTE: AVAILABILITY OF SCIENTISTS IS SUBJECT TO CHANGE.

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SCIENTIFIC AMERICAN FRONTIERS

Watch It On PBS

SCIENTIFIC AMERICAN FRONTIERS airs on PBS with five new programs each season, October through April. Each hour-long special includes a variety of intriguing science stories based on a single theme.

SHOW 901: Science in Paradise

***INTERNATIONAL SPECIAL!* WEDNESDAY, OCTOBER 7, 1998**

Dive into the beautiful waters of the Caribbean and find out what scientists are learning about the science of paradise, from underwater coral reefs to asteroids in outer space and a devastating volcano here on Earth.

THIS ISSUE **SHOW 902:** Journey to Mars

WEDNESDAY, NOVEMBER 11, 1998

3 . . . 2 . . . 1 . . . Blast off to Mars! Sometime early in the next century, humans may take off on the first manned mission to the red planet. Learn about scientists' exciting projects, from inflatable habitats to the search for Martian life.

SHOW 903: Animal Einsteins

WEDNESDAY, JANUARY 20, 1999

Dr. Dolittle isn't the only person who talks to the animals. Scientists tell us we can learn much from our furry, feathered and finned friends. Find out what the latest studies reveal about birds, sea lions, chimps and tamarins.

SHOW 904: Life's Little Questions

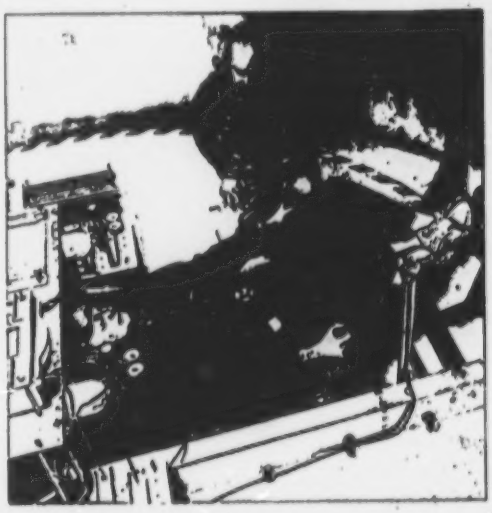
WEDNESDAY, FEBRUARY 24, 1999

What makes hot peppers hot? Why do traffic jams happen? What's the best way to combat jet lag? Join host Alan Alda in a scientific quest to answer some of the little questions that affect us in sometimes big ways.

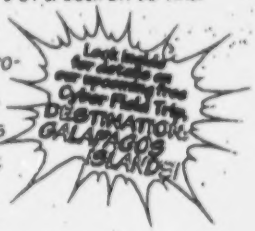
SHOW 905: Spiders!

WEDNESDAY, APRIL 14, 1999

Meet just a few of the 39,000 known spider species — including the world's largest, a 10-inch tarantula, and a cyberspider that lives inside a computer. And, learn about a 20th-century solution to an ancient fear, arachnophobia.



In this episode, SCIENTIFIC AMERICAN FRONTIERS host Alan Alda tests an experimental piece of exercise equipment, part of a search to find ways to keep astronauts in shape while living in microgravity. As Alan finds out, the new exercise machines are not quite like those at the gym on Earth!



SEE IT ON PBS

UNDERWRITTEN BY GTE CORPORATION

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Requested Teaching Materials for
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AIR DATE:
November 11, 1998

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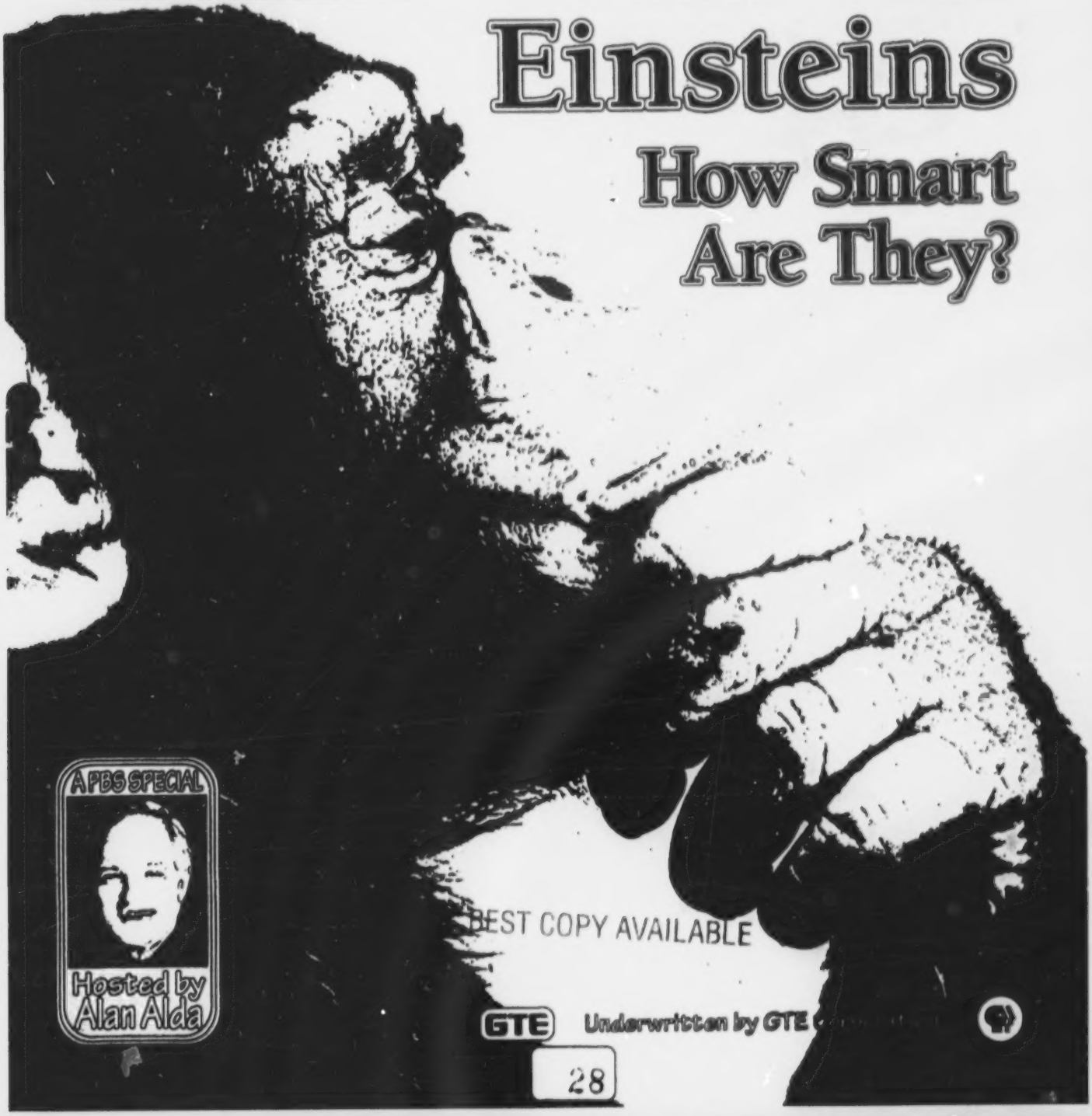
SCIENTIFIC AMERICAN FRONTIERS

TEACHING GUIDE FOR SHOW 903
JANUARY 20, 1999 • 8–9 P.M.

Animal Einsteins

How Smart Are They?



A PBS SPECIAL

Hosted by Alan Alda

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SCIENTIFIC AMERICAN FRONTIERS

Show 903: Animal Einsteins

January 20, 1999 • 8 p.m. on PBS (CHECK LOCAL LISTINGS)

ROCKY the sea lion gives a warm — if wet — welcome to SCIENTIFIC AMERICAN FRONTIERS host Alan Alda. With the help of trainers at the University of California, Santa Cruz, Rocky has learned to understand a special sign language. Fetch, touch, ball, bat and frisbee are just part of her vocabulary. Join Alan as he visits with Rocky and other **Animal Einsteins** in a quest to find out how — and how much — animals think.

5 IF ONLY THEY COULD TALK!

Meet a pig and a sea lion that understand sign language, and a parrot that speaks English.

ACTIVITY: Solve a puzzle by decoding symbols

RUNNING TIME: 9:58

6 WHO NEEDS WORDS, ANYWAY?

Is language essential to thought? Watch as researchers try to answer that question.

ACTIVITY: Observing animal communication

RUNNING TIME: 10:47

7 NUMBER CRUNCHERS

Meet monkeys that count and chimpanzees that do fractions.

ACTIVITY: Understanding binary counting systems

RUNNING TIME: 7:15

8 FIGURE THAT ONE OUT

Watch as ravens and cotton-top tamarins solve some tricky problems.

ACTIVITY: Puzzling situations

RUNNING TIME: 7:43

9 NO FOOLS ABOUT TOOLS

What does animals' ability to use tools tell us about their intelligence?

ACTIVITY: Define and measure dog IQ

RUNNING TIME: 4:48

10 THINKING ABOUT THINKING

Chimps and monkeys seem to understand what other animals think.

ACTIVITY: Be an animal observer

RUNNING TIME: 10:20

Plus, in every issue . . .

4 VIEWER CHALLENGE

Guided viewing quiz questions, T-shirt prizes!

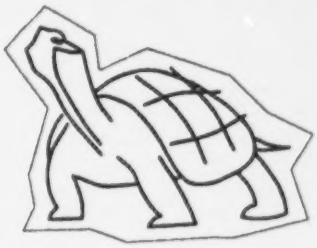
11 FRONTIERS ONLINE

Visit us at www.pbs.org/saf/

SCIENTIFIC AMERICAN FRONTIERS is made possible by an underwriting grant from GTE Corporation. The series is produced by The Chedd-Angier Production Company in association with *Scientific American* magazine and presented to PBS by Connecticut Public Television. Classroom materials produced by Media Management Services, Inc.

GTE

"Science isn't about guys in white lab coats with big vocabularies," says David Anderson, who studies unusual seabirds in the Galapagos Islands. "It's about curious people asking questions about nature and finding the answers by collecting data. Kids can be scientists themselves." Anderson is one of the scientists featured in a new area on the FRONTIERS website: Cool Careers. Check it out for yourself at www.pbs.org/saf/. You can also learn more about Anderson's work and find out what happened when SCIENTIFIC AMERICAN FRONTIERS visited the Galapagos for a special cyber field trip. The entire trip — plus classroom activities you can use with your students — is available online at www.pbs.org/saf/galapagos.html.



CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
BIOLOGY/LIFE SCIENCE: birds, mammals, nervous system **HUMANITIES/LANGUAGE ARTS:** speech **PSYCHOLOGY:** learning	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** Biological Evolution, Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8:** Nature of Science, History of Science; **9-12:** Nature of Scientific Knowledge, Historical Perspectives

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
BIOLOGY/LIFE SCIENCE: marine mammals, primates **GENETICS:** evolution **HUMANITIES/LANGUAGE ARTS:** speech **PSYCHOLOGY:** cognition, communication	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** Biological Evolution, Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
BIOLOGY/LIFE SCIENCE: primates **MATH:** binary numbers **PSYCHOLOGY:** learning	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** Biological Evolution, Behavior of Organisms / **HISTORY & NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
BIOLOGY/LIFE SCIENCE: birds, primates **HUMANITIES/LANGUAGE ARTS** **PSYCHOLOGY:** cognition, problem solving	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** Biological Evolution, Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8, 9-12:** Science as a Human Endeavor

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
BIOLOGY/LIFE SCIENCE: primates **HUMANITIES/LANGUAGE ARTS** **PSYCHOLOGY:** intelligence, problem-solving **TECHNOLOGY:** tools	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** Behavior of Organisms / **SCIENCE & TECHNOLOGY: 5-8, 9-12:** Abilities of Technological Design, Understandings About Science and Technology / **HISTORY & NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS	NATIONAL SCIENCE EDUCATION STANDARDS
BIOLOGY/LIFE SCIENCE: evolution, nervous system, primates **HUMANITIES/LANGUAGE ARTS** **PSYCHOLOGY:** intelligence, learning	**SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8:** Structure and Function in Living Systems, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8, 9-12:** Science as a Human Endeavor

FREE TAPING RIGHTS

- As a teacher, you have free off-air taping rights in perpetuity for classroom use.
- Always check TV listings to confirm air date and time.
- If you can't find the show in your TV listings, call your local PBS station.
- Educators may photocopy all materials in this guide for classroom use.
- Do you need help? Call the FRONTIERS School Program at 800-315-5010.
- Videotapes of past shows can be purchased ($21.97 each). Call 800-315-5010.

LET US HEAR FROM YOU!

Do you have a comment or question about FRONTIERS? Do you know someone who wants to sign up for free teaching materials? PLEASE CONTACT US . . .
BY MAIL: SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425 • PHONE: 800-315-5010 • FAX: 215-579-8589 • E-MAIL: saf@pbs.org

SCIENTIFIC AMERICAN FRONTIERS is closed-captioned for the hearing-impaired and is narrated by Descriptive Video Service (DVS) for visually impaired audiences. The series and School Program are endorsed by the National Science Teachers Association (NSTA) and the National Education Association (NEA).

VIEWER CHALLENGE

Animal Einsteins

SCIENTIFIC AMERICAN FRONTIERS

Show 903 • January 20, 1999, at 8 p.m. on PBS (CHECK LOCAL LISTINGS)
Watch SCIENTIFIC AMERICAN FRONTIERS for answers to the questions on this page.
Answer the 10 questions correctly and you'll be eligible to win a FRONTIERS T-shirt!

Reminder: Cover the answer key at the bottom of this page before photocopying.

Student's Name: _____

Teacher's Name & Course: _____

If Only They Could Talk!

1. The horse called Clever Hans was found to be doing this when he "answered" questions put to him.

_____

_____

2. How is Rocky the sea lion's use of sign language different from Hamlet the pig's?

_____

_____

Who Needs Words, Anyway?

3. How might the ability to classify groups be important to a sea lion in the wild?

_____

_____

4. Until young children are about this age, they do not understand the concept of a model room symbolizing a large room.

☐ a. 1 year ☐ b. 18 months ☐ c. 2 years ☐ d. 3 years

Number Crunchers

5. To assure valid results in the apple counting experiment and avoid the "Clever Hans effect," scientists must do this:

☐ a. blindfold the researchers
☐ b. run the same test with different conditions
☐ c. repeat the experiment with the same researcher, exactly the same way
☐ d. use the same researchers all the time

6. What makes the researcher conclude that the monkey or baby is surprised by what is seen on the stage?

_____

Figure That One Out

7. Ravens belong to this family of birds, believed to be one of the most intelligent among birds.

_____

No Fools About Tools

8. What is one of the best ways to test an animal's intelligence?

_____

_____

9. The experiment with the cotton-top tamarin attempts to determine if the tamarin knows:

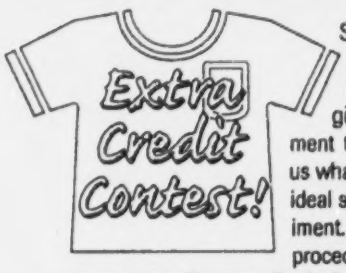
☐ a. different colors.
☐ b. left from right.
☐ c. what features of a tool make it effective.
☐ d. how to find food in the wild.

Thinking About Thinking

10. What is the big question being explored in the experiment with Darryl the chimpanzee?

_____

_____



So you think your pet is smarter than the rest? Design an original scientific experiment to prove it! First, tell us what makes your pet an ideal subject for the experiment. Then describe the procedure you used to test your pet's intelligence. Don't forget to include the results! Send your entry by **February 19, 1999**, to Extra Credit Contest at the address to the right. The most well-founded experiments will be posted in the Polls & Prizes section of the FRONTIERS website and the winners will get a T-shirt. ***Good luck!***

FOR TEACHERS ONLY

When completed, this page can become an entry to the FRONTIERS T-shirt contest; 20 winners (10 students, 10 teachers) will be drawn at random for each show. To enter the T-shirt drawing, send all completed challenges in one envelope with a cover sheet to: Viewer Challenge, SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425. Mail completed entries by **February 19, 1999**.

TIP: You can download these questions at **www.pbs.org/saf/** (click "In the Classroom").

IMPORTANT!! Please include a separate cover sheet and tell us:

- number of challenges submitted
- teacher's name
- grade and course
- school name, address and phone number
- where your students watched the show — at home, at school or both
- the name of your students' favorite story in this show (conduct a quick poll to find out)

Thank you!

Answers to the Viewer Challenge: 1. picking up clues from someone in the audience 2. Rocky is able to use the sign language in different ways 3. sort out friend and foe 4. d 5. b 6. looking time or time the subject stares 7. crows 8. see how it handles a difficult situation for the first time 9. c 10. is the chimp aware of what other chimps know or don't know?

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SCIENTIFIC AMERICAN FRONTIERS

IF ONLY THEY COULD TALK!

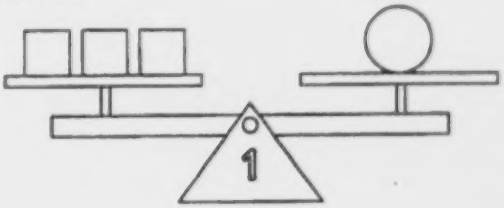
Do animals communicate? Do they develop languages? Scientists are studying nonhuman primates, whales, dolphins and a variety of other animals to explore these questions and understand how animals convey and comprehend information. In this story, meet Hamlet the pig, Rocky the sea lion and the amazing African gray parrot named Alex, and judge their linguistic abilities for yourself.

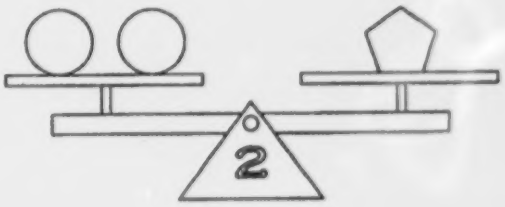
A Visual Balancing Act

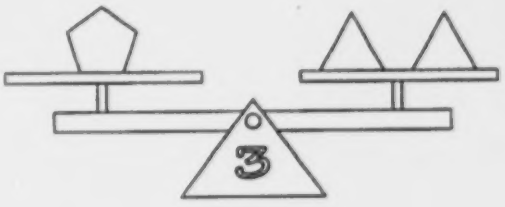
As you'll see on FRONTIERS, animals can be taught to associate abstract concepts or signs with specific objects or actions. Such symbolism can be said to be the underlying basis of a language.

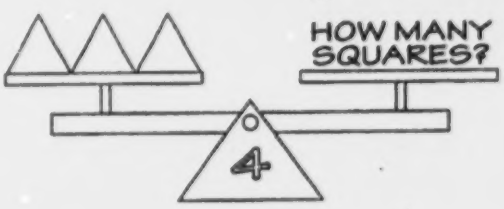
Chimpanzees and other animals like dolphins and Rocky the sea lion (seen on FRONTIERS) have been taught to recognize a simple sign language, in which a sign or symbol stands for something else. The animals could be said to be decoding symbols, which is one of the same tasks children must master when they learn to read.

Here's your chance to do some simple decoding and manipulating of symbols. Analyze the puzzle about balanced masses on this page. Determine how many squares it takes to balance three triangles. To solve this challenge, you'll first need to figure out the code. Just for fun, once you've solved this puzzle, make up similar puzzles for your classmates.









QUESTIONS

Review the steps in the scientific method: observe, hypothesize, predict, test, modify, repeat. Then, as you watch **Animal Einsteins**, select one or two experiments from the show to use as examples in a discussion about scientific methods and experiment design. Think about the following questions:

1. What hypothesis is the scientist trying to prove in each research project? How does the experiment test the hypothesis?
2. Do you think the scientists' research projects demonstrate good experimental designs? How might you conduct the research?
3. What other questions or theories would you like to explore about a particular animal featured in one of the stories? Design an experiment to test your theory.
4. What makes humans human? What is the nature of intelligence? How can we test it in people and animals?

SEE PAGE 11

Irene Pepperberg
answers your questions about Alex the parrot online.
www.pbs.org/saf/einsteins.html

EXTENSIONS

1. Investigate some of the groundbreaking work that's been done to teach sign language to animals, especially to dolphins, chimps and Koko the gorilla.
2. Until Irene Pepperberg started publishing her work with Alex, most people assumed that parrots simply mimicked people. Do you think Alex really understands what he's saying? How would you know? Think about the distinctions between communication and language as you watch this program.
3. After watching this story about Alex, would you ever call someone a "birdbrain"? Why do you think the term originated? Want to learn more about Alex? You can read an interview with him in *Scientific American* magazine, April 1996 (find it online at www.sciam.com).

Solution to puzzle: 3 squares

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SCIENTIFIC AMERICAN FRONTIERS

WHO NEEDS WORDS, ANYWAY?

Can animals think without words? Do they think and reason without a formal language? Can animals learn to comprehend abstract concepts? Researchers work with Rio the sea lion and Sheba the chimp as part of ongoing explorations to investigate these questions. The animals' mental abilities are compared with those of a young child.

Listen to the Animals

It's long been assumed that because animals do not possess a true language, they cannot be capable of abstract thoughts. Many studies, like those seen on FRONTIERS, are challenging this assumption. Exploring how animals think is important, because observations may tell us more about the human mind and how it evolved.

Before we can talk with the animals, we need to find out how animals "talk" with each other. In this activity, you'll observe and listen to see if specific animal calls are associated with specific actions.

PROCEDURE

PART 1: WHAT DO YOU KNOW?

1. Work in groups of two students each to compile a list of different kinds of communications you've witnessed among animals. (Examples might include dogs growling, cats hissing or birds calling.)
2. Write the examples on the board and determine which animals you think communicate more than others.
3. Select one or two animals from the list to observe. (Birds, especially in spring, are a good choice. You could also observe animals at a zoo or pet store.)

SEE PAGE 11

Ronald J. Schusterman of the University of California, Santa Cruz, answers your questions online.
www.pbs.org/saf/einsteins.html

PART 2: OBSERVING ANIMAL COMMUNICATIONS

1. If you have access to a video camera, set it up so you can videotape actions and sounds that the animal makes. If you don't have a camera, use a journal to record observations.
2. Make sure you sit quietly and observe for a minimum of 15 minutes. Patience is key to studying animal communication or any kind of animal behavior.
3. Write down any sounds you hear and the actions associated with those sounds. (For example, a bird might sing on a perch, look around, then move to another perch.)

PART 3: ANALYZE OBSERVATIONS

Prepare a report on your observations. If you made recordings, play them and explain what kind of communication you think is taking place and why. For example, a bird singing a specific song might be establishing boundaries of its territory or attracting a mate.

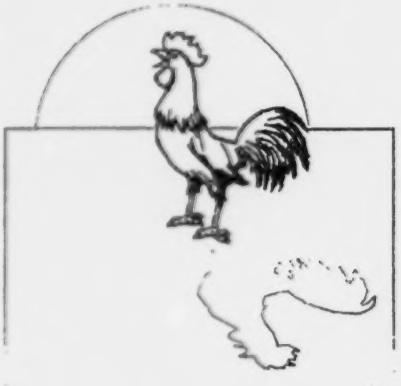
QUESTIONS

1. How many sounds seemed to be related to a specific activity?
2. Do you consider the communication you observed to be an animal "language"? In your opinion, is animal communication the same as a language? (Not even the experts agree about these questions!)
3. Were any other types of communication associated with the sound? (For example, a dog may growl and also bare its teeth.) If so, do you think the sounds would be as effective without these other displays?

EXTENSIONS

1. Animal researchers have been exploring the ways killer whales, dolphins and other marine mammals communicate. Find out more about these animals' linguistic skills. Do you think they use "language"?
2. Find out more about the primates in this program. Compare New World (South American) tamarins with Old World (African) chimpanzees. How are great apes, monkeys and other primates related?
3. Imagine you and some friends lived ages ago, in a time before language and speech. How would you communicate with your friends?
4. Research the differences in primate cranial capacity and anatomy required for speech. Start your research by searching the Web under key words like "animal intelligence" or "animal language."
5. Scientists working to identify the human genome are also studying the genome of the chimpanzee. Scientists suspect only about 50 genes account for cognitive differences between people and chimpanzees, out of the 100,000 or so genes that make up humans and chimps. The DNA of chimps and humans is on average about 98.4% identical because the two species are believed to have shared an ancestor about five million years ago. Explore the cognitive differences and similarities.
6. Koko the lowland gorilla made history in April 1998, when she participated in the first ever interspecies chat on AOL. More than 30,000 people logged on. You can read the transcript and learn more about Koko and other gorillas learning American Sign Language at:

www.gorilla.org/index.html



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SCIENTIFIC AMERICAN FRONTIERS

NUMBER CRUNCHERS

Throughout much of human history, it's been assumed that the use of numbers is unique to people. Recent studies have cast doubt on that assumption, however, as animal behaviorists like the ones seen on this show demonstrate that primates can manipulate numbers. Watch as rhesus monkeys test their math skills and a chimpanzee works with fractions.

M&M Math

Numbers play a significant role in human communication. We humans use a base 10 (decimal) system of numbers that is presumed to have originated because we have 10 fingers and 10 toes. In this system, place values are expressed in powers of 10.

Other cultures in history developed various counting systems using other bases. The early Mayans used a base 20 system; ancient Romans used a base 12 system.

Computers use a language called the binary system. Only the numbers zero and one are used to signify a switch being turned off or on. In a binary system, place values are expressed in powers of two. In this activity, you'll use a model to understand the binary counting system.

MATERIALS

- ☐ paper
- ☐ pencil
- ☐ M&Ms candy (or other small items)

PROCEDURE

In a decimal system, you multiply by 10 for each place you move to the left of the decimal point. To visualize the decimal system, create a chart four columns wide. Label the columns with place values from left to right as follows: 1000, 100, 10 and 1. You'll use M&Ms or other small placeholders to help you count. To represent the number 1412, place one M&M placeholder in the 1000 column, four M&Ms in the 100 column, 1 M&M in the 10 column and 2 M&Ms in the 1 column. You can use your chart to help write out the number in expanded notation: $(1\times1000)+(4\times100)+(1\times10)+(2\times1)=1412$

Counting in the binary system is a little more challenging, because this system uses only two numbers: 0 and 1.

To visualize this system, make a chart seven columns wide (**FIGURE 1**). Label the columns with place values in powers of two, from left to right: 64, 32, 16, 8, 4, 2 and 1. Draw one circle in each column as shown. In this model, like in the decimal model, your M&M placeholder indicates the number 1; an empty space represents zero. To count from 1 to 5, express numbers as follows:

1: Place an M&M in the 1 column. In expanded notation, this would be expressed as $(1\times1)=1$.

2: Clear off the 1 column. Place an M&M in the 2 column: $(1\times2)+(0\times1)=2$.

3: Add an M&M to the 1 column: $(1\times2)+(1\times1)=3$.

4: Clear off all M&Ms and place an M&M in the 4 column: $(1\times4)+(0\times2)+(0\times1)=4$.

5: Add an M&M to the 1 column: $(1\times4)+(0\times2)+(1\times1)=5$.

Using your chart, figure out how to finish counting to 10 and write the answers on your paper, using both expanded notation and binary numbers. What base 10 number is represented by the base 2 (binary) number 10101 (**FIGURE 2**)? To find the answer, use expanded notation:
$(1\times16)+(0\times8)+(1\times4)+(0\times2)+(1\times1)=21$

What base 10 numbers are represented by the base 2 numbers 1100, 1110, 11011, 100101, 1010101? What's the highest base 10 number you can express using the binary number chart shown here?

FIGURE 1

64	32	16	8	4	2	1
○	○	○	○	○	○	○

FIGURE 2

64	32	16	8	4	2	1
○	○	●	○	●	○	●

QUESTIONS

1. The decimal (base 10) system is believed to have originated because humans have 10 fingers and 10 toes. What base system might a giraffe use? What about a chimpanzee? If nonhuman animals possess a sense of math, do you think they count the same way we do?
3. Do you think the rhesus monkeys seen on FRONTIERS are really counting the apple pieces? Explain.
4. It's been said that crows can count hunters in a field, and are able to distinguish between four and five hunters. How would you design an experiment to test this?

EXTENSIONS

1. Create a way to use binary numbers to represent the alphabet. Send a coded message to a friend.
2. Find out more about the Mayan and Roman base systems. Why do you think they developed as they did?

SEE PAGE 11

Psychologist **Susan Carey**, who studies primates' counting skills, answers your questions online.
www.pbs.org/saf/einsteins.html

Answers: 110=6; 111=7; 1000=8; 1001=9; 1010=10; 1100=12; 1110=14; 11011=27; 100101=37; 1010101=85. The highest number you can express is 127 (1111111).

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FIGURE THAT ONE OUT

Ravens and other birds in the crow family are believed to be smart, but how intelligent are they — and how would anyone know they're intelligent? One of the ways to assess animal intelligence is to see how the animal reacts to a difficult situation for the first time. See what happens when a raven and later a tamarin must figure how to solve some unusual problems.

Puzzling Situations

On FRONTIERS you saw how different animals approach and solve various problems. Problem-solving techniques have enabled animals to survive successfully; if animals couldn't solve problems, they would not be able to find food and fend off predators. Problem-solving techniques vary from species to species, but are not unique to humans. Studying how different animals solve problems may give us insights into animals and perhaps people's behavior, as well.

In this activity you will observe how different people solve a puzzle. Select a few people to be testers and others to solve the puzzles shown here.

MATERIALS

- ☐ stopwatch
- ☐ paper
- ☐ pencil
- ☐ toothpicks
- ☐ index cards
- ☐ scissors

PROCEDURE

PART 1: SET UP THE EXPERIMENT

1. Place 12 toothpicks into the pattern shown:

2. Have a pencil and piece of paper ready to record your observations.
3. Tell your classmate to make two four-sided shapes of different sizes by removing two toothpicks. (**NOTE:** The solution does not require that all remaining toothpicks be part of the two shapes.)

PART 2: GATHER DATA

1. Observe how the subject (your classmate) solves the problem.
2. Write down how long your classmate studies the problem before beginning, how long he or she spends manipulating the puzzle and any verbal or nonverbal language used to solve it.
3. Repeat the process with two or three other subjects.
4. Compare the problem-solving techniques people used.
5. Create a graph or poster that represents your data in a clear and concise way.
6. Try a variation of the same puzzle. Use the same toothpick pattern but ask subjects to move (not remove) three toothpicks to make three equal squares. Did subjects solve the problem the same way they solved the first puzzle?

PART 3: SWITCH PLACES

1. Change roles, so the tester becomes the subject.
2. Follow the same process of observation while the subject solves the puzzle.
3. In this puzzle, instruct the subject to duplicate the shape illustrated above, constructed from a single index card. No pieces have been removed from or added to the card. Its odd shape requires some carefully placed snips and a mind-bending twist. Can you duplicate this shape using an index card and scissors?

Reprinted by permission. For more puzzles, see Visual Thinking Puzzles by Michael DiSpezio, Sterling Publishers, ISBN 0-8069-9975-8. ©1998. (Available through most bookstores and NSTA, 800-722-NSTA.)

QUESTIONS

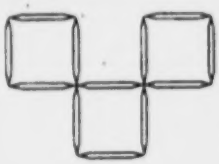
1. Describe different ways people solved the problem. Which seemed to be the most successful techniques?
2. Try these puzzles with people of different ages and compare results.
3. What is the most difficult aspect of studying behavior in humans? Do you think animal behaviorists have the same problems?
4. Compare the ways the raven and tamarin solved the problems presented to them. Do you think the tamarin really understands the physical concept of gravity, or is the animal simply figuring out how the world works? Similarly, when babies throw objects out of their cribs and high chairs, do you think they are "testing gravity" or finding out how things work? To what extent do human researchers need to be careful to avoid projecting too much onto the subject?

SEE PAGE 11

Bernd Heinrich from the University of Vermont answers your questions online.
www.pbs.org/saf/einsteins.html

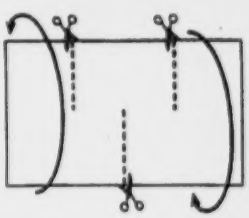
PART ONE POSSIBLE SOLUTION:

PART TWO POSSIBLE SOLUTION:



PART THREE SOLUTION:

The flap is made by placing three cuts as shown here. Then, the right and left card halves are twisted in opposite directions and folded so that the flap sticks out from the middle of the twist.



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NO FOOLS ABOUT TOOLS

Scientists and philosophers have long considered the ability to use tools unique to humans. This assumption was challenged in the mid-20th century when scientists began observing animals using tools in the wild. For example, chimpanzees use sticks to collect termites. In this story, watch a cotton-top tamarin put some lessons about tool use into practice.

Define and Test Canine IQ

Scientists and philosophers have pointed to tool use as one of the significant behaviors that distinguish humans from other primates. Researchers have found evidence of crude tools being used by *Homo habilis* two million years ago. Today, recent findings about animals' use of tools have added to the debate over what constitutes intelligence.

Scientists have long argued about what intelligence is. Once they agree on a definition of intelligence, they can design experiments or questionnaires to measure it.

In this activity, you'll attempt to define intelligence in dogs, then design a questionnaire to collect data and determine the breed of dog with the highest intelligence.

PROCEDURE

PART 1: DEFINE INTELLIGENCE IN DOGS

1. As a class or group, brainstorm characteristics of intelligence in dogs. (Examples might include: understands voice commands, understands hand signals.) List as many ideas as you can on the board.
2. Discuss the list when it's complete. Delete any characteristics that are not agreed upon by the majority. From the remaining list, vote for the top 10 characteristics that students want to test.
3. Using the top 10 list, formulate questions that will let you rate how a specific breed of dog measures up. Make sure the questionnaire has a space to enter breed and source of information. The following sample questions are adapted from the September 1997 issue of *Dog Fancy* magazine:

   Please rate the following on a scale from 1 (never) to 6 (always):

   ____ Does this breed understand voice commands?

   ____ Does this breed understand hand signals?

PART 2: COLLECT & ANALYZE DATA

1. You can collect data in a variety of ways. For example, you can ask classmates with different breeds of dogs to fill out the questionnaire, or you can call local veterinarians and dog trainers, or use the Web to research different breeds.
2. Average the ratings for each breed based on the questionnaires and rank the breeds you researched from highest score (most intelligent) to lowest (least intelligent).
3. Once you have researched and ranked the breeds, visit the following website, which lists breeds from most to least intelligent, to see how your dog IQ list compares:

   www.petrix.com/dogint/intelligence.html

QUESTIONS

1. Was it difficult to agree on a definition and a way to measure intelligence? Why?
2. If you own a dog or know of a dog that does tricks, compare the dog's performance with that of Clever Hans, the horse seen in the introduction to this show. Why is it critical to avoid giving clues in real experiments?
3. The tamarin in this story was trained to use "tools." Unlike chimps, tamarins have not been observed to use tools in the wild. What do you think is a truer measure of learning – the ability to repeat a trained or learned skill or the ability to apply what one has learned to other situations or environments? Do you think the tamarin would be able to apply any of its training to its life in the wild? What's the difference between using and making tools? Explain.

EXTENSIONS

1. Think of all the domestic and wild animals you've ever known or observed. Can you think of any behavior that might be considered using tools? For example, if a cat wakes up its owner every morning by knocking something on the floor, is the cat using a tool, or just repeating effective behavior? What does it mean to use a tool? What about tool use and invention distinguishes humans?
2. Do you think intelligence varies within a specific breed of dog? What might cause this to happen?
3. Design an IQ test for cats and other animals to see how they rate. Can you compare different species?
4. Think of animals you or your friends have had as pets, or animals you've observed outdoors. Have you ever described one of these animals as "smart" or "intelligent"? What about the animal's behavior made you describe it as more intelligent than others?
5. What do you think is a true measure of intelligence in humans and nonhuman animals? Do you think humans are more intelligent than other animals? If so, does our human intelligence make us superior?
6. Research the findings by paleontologists and archaeologists about the use and manufacture of tools by our ancestors.

SEE PAGE 11

Marc Hauser answers your questions about tamarins' problem-solving abilities online.
www.pbs.org/saf/einsteins.html

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SCIENTIFIC AMERICAN FRONTIERS

SHOW #203

THINKING ABOUT THINKING

Can animals empathize? To find out, Alan Alda participates in a study designed by primatologists that explores a chimpanzee's awareness of other chimps. The experiment will attempt to find out if a chimpanzee can put himself in the place of another chimp. A comparative study with a young child explores similar issues from the human standpoint.

A NOTE OF CAUTION TO VIEWERS: *In this story, the chimpanzee appears distressed when he thinks it's time for his annual physical. Educators may wish to preview the segment, as it contains sensitive content.*

Be an Ethologist

Scientists who study animals will tell you that working with animals requires incredible patience. It's not easy to sit in the field and watch a family of monkeys for hours, days, even weeks. But they'll also tell you that the rewards are worth the effort.

Here is your chance to become an ethologist — a scientist who studies behavior of animals in their natural environments. You can start with your pet or a friend's pet to observe an animal's behavior when it is alone. Then try to find a group of animals for observation. You can find groups of animals at a zoo, wildlife habitat or animal park, or at a pet store or kennel — even at a local park where people walk their pets.

SEE PAGE 11

Sally Boysen answers your questions about chimp communication online. **www.pbs.org/saf/einsteins.html**

	OBSERVATIONS		
1.	Animal's common name:	10.	Does there seem to be an order of dominance? Explain.
2.	Animal's scientific name:	11.	What is the makeup of the group, in terms of adults and young?
3.	Description of current habitat:	12.	Describe the behavior of young and adult animals.
4.	Description of natural habitat:	13.	Do males and females exhibit different behavior? Toward each other? Toward the young?
5.	Time and date of observation:	14.	Do the animals communicate with each other? Describe.
6.	Describe the animal's activities during the observation period:	15.	Describe their interactions with each other.
7.	Is the animal solitary or does it hang out in a group?	16.	How do your observations of a solitary animal's activities differ from animals' activities in a group?
8.	If the animal is part of a group, how many are in the group?		
9.	Do members of the group interact with each other? Describe.		

You'll want to study your selected animal subject(s) over a period of time, if possible. If not, then try to spend at least an hour observing. Remember, when you are an observer, you should interact with your subject(s) as little as possible. Remain still and become a part of their environment.

Record all your observations as entries in a notebook. Use the questions above as a guide. (If you cannot observe any animals, use the Web to find out more.) After completing your observations, prepare a final report. You may wish to include video clips or photographs.

QUESTIONS

1. Findings by animal behaviorists like those seen on FRONTIERS are causing people to rethink their assumptions about other animals. As you watched this show, did you find yourself surprised by some of the studies and findings? Explain.
2. Imagine you are an animal, observing your human trainer or owner. Put yourself in the place of that animal. How do you perceive the human? What would you like to find out about the human trainer? What kind of experiment would you set up to test the human's intelligence – from your perspective as an animal?
3. Think of all the animals you watched on this show. Create a hypothesis about some aspect of that animal's life that you'd like to understand better. Then design an experiment to test it.

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Selected Websites for Show 903

Visit these sites to learn more about topics on **Animal Einsteins**. You can find more links to related sites online at www.pbs.org/saf/.

Animals and Research Areas in 903

www.cages.org/research/pepperberg/index.html
Irene Pepperberg's home page. Alex, the African gray parrot. Photos, scientific articles.

www.cwu.edu/~cwuchci/
Chimpanzee and Human Communication Institute. Studies, links, FAQ.

www.wjh.harvard.edu/~mnkylab/media/media.html
Sounds and videos of cotton-top tamarins and other primates being studied.

www.selu.com/~bio/PrimateGallery/main.html
Images and information on living primates. Natural history, vocal calls, animations.

www.selu.com/~bio/cottontop
Project Tamarin. Conservation, facts, photos, links about these New World primates.

www.nabt.org/Animals.html
National Association of Biology Teachers statements on animals in the classroom and other ethical and scientific issues.

www.primate.wisc.edu/pin/
Extensive research on primates: language, tool use, behavior, politics, humor, even related careers.

www.leighty.net/~jhigbee/Bird_Intelligence.htm
Bird intelligence studies.

www.gorilla.org
The Gorilla Foundation. Teaching American Sign Language to gorillas.

Animals and Animal Studies/Sciences

golgi.harvard.edu/biopages/evolution.html
Virtual Library of evolution and the biosciences. Links, books, software, resources. Paleontology, natural history.

www.cisab.indiana.edu/ABS/index.html
Animal Behavior Society. Resources, journals, careers in ethology, applied animal behavior, organizations, science libraries.

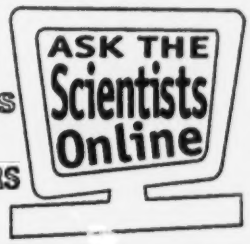
weber.u.washington.edu/~jahayes/evolution/index.html
The Sci.Bio.Evolution page. Fossils, biotech, artificial life, dinosaurs.

netvet.wustl.edu/ssi.htm
Electronic Zoo, from amphibians to zoo animals. Includes sounds and images.

vlib.stanford.edu/Biosciences.html
Virtual Library. Animal health, well being, rights. Genetics, zoos, fields of research.

At press time, the online features and sites listed here were current. Due to the rapidly changing online world, some may have changed or may no longer be available. We recommend that you preview sites before passing them on to students.

Explore Animal Einsteins with FRONTIERS Online!



After **Animal Einsteins** airs, specialists from the show will answer questions about their work. The scientists featured below will be available from January 20 to February 5, 1999. To participate in Ask the Scientists, visit FRONTIERS online at www.pbs.org/saf/.

IF ONLY THEY COULD TALK!

Irene Pepperberg of the University of Arizona works with Alex, a parrot with amazing skills. Find out what her research tells us about how Alex and other creatures communicate.

WHO NEEDS WORDS, ANYWAY?

Ronald Schusterman of the University of California, Santa Cruz, answers questions about sea lions' communication and reasoning abilities. (Schusterman also answers questions about his research featured in "If Only They Could Talk!")

NUMBER CRUNCHERS

Psychologist Susan Carey of New York University explores primates' counting skills as she looks for the roots of human thinking. Ask Carey about her experiments with monkeys in Puerto Rico.

FIGURE THAT ONE OUT

Ask Bernd Heinrich of the University of Vermont what his research with an aviary of ravens tells us about the capabilities of these clever creatures.

NO FOOLS ABOUT TOOLS

Marc Hauser has carefully designed several experiments to test the problem-solving abilities of tamarins. Now he gives viewers a report from his lab at Harvard University. (Hauser also answers questions about his research featured in "Figure That One Out.")

THINKING ABOUT THINKING

Sally Boysen of Ohio State University tells you more about her work with chimps and how they communicate. (Boysen also answers questions about her research with pigs featured in "If Only They Could Talk!" and additional research with chimps in "Who Needs Words, Anyway?")

HOW TO "ASK THE SCIENTISTS"

Visit SCIENTIFIC AMERICAN FRONTIERS on PBS Online at www.pbs.org/saf/. Click on "Ask the Scientists" to send your question(s). Scientists' answers will be posted online for FRONTIERS viewers to read.

Remember to e-mail your questions by February 5, 1999!

PBS online

NOTE: AVAILABILITY OF SCIENTISTS IS SUBJECT TO CHANGE.

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SCIENTIFIC AMERICAN FRONTIERS

Watch It On PBS

SCIENTIFIC AMERICAN FRONTIERS airs on PBS with five new programs each season, October through April. Each hour-long special includes a variety of intriguing science stories based on a single theme.

SHOW 901: Science in Paradise

***INTERNATIONAL SPECIAL!* WEDNESDAY, OCTOBER 7, 1998**

Dive into the beautiful waters of the Caribbean and find out what scientists are learning about the science of paradise, from underwater coral reefs to asteroids in outer space and a devastating volcano here on Earth.

SHOW 902: Journey to Mars

WEDNESDAY, NOVEMBER 11, 1998

3 . . . 2 . . . 1 . . . Blast off to Mars! Sometime early in the next century, humans may take off on the first manned mission to the red planet. Learn about scientists' exciting projects, from inflatable habitats to the search for Martian life.

THIS ISSUE ➔ SHOW 903: Animal Einsteins

WEDNESDAY, JANUARY 20, 1999

Dr. Dolittle isn't the only person who talks to the animals. Scientists tell us we can learn much from our furry, feathered and finned friends. Find out what the latest studies reveal about birds, sea lions, chimps and tamarins.

SHOW 904: Life's Little Questions

WEDNESDAY, FEBRUARY 24, 1999

What makes hot peppers hot? Why do traffic jams happen? What's the best way to combat jet lag? Join host Alan Alda in a scientific quest to answer some of the little questions that affect us in sometimes big ways.

SHOW 905: Spiders!

WEDNESDAY, APRIL 21, 1999

Meet just a few of the 39,000 known spider species — including the world's largest, a 10-inch tarantula, and a cyberspider that lives inside a computer. And, learn about a 20th-century solution to an ancient fear, arachnophobia.

IS A BOX containing three pieces of apple better than a box with two pieces? These rhesus monkeys know the answer. Join FRONTIERS host Alan Alda to meet these and other **Animal Einsteins**.

SEE IT ON PBS

UNDERWRITTEN BY GTE CORPORATION

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SCIENTIFIC AMERICAN FRONTIERS

INSIDE:
Requested Teaching Materials for
ANIMAL EINSTEINS

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SCIENTIFIC AMERICAN FRONTIERS

TEACHING GUIDE FOR SHOW 904
FEBRUARY 24, 1999 • 8–9 P.M.

Life's Little Questions

Why do coffee stains leave rings?

How do bees fly?

Why are chile peppers hot?

. . . and Some Very Big Answers

Can you beat jet lag?

Why does traffic jam?

BEST COPY AVAILABLE

Underwritten by GTE Corporation

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SCIENTIFIC AMERICAN FRONTIERS

Show 904: Life's Little Questions

February 24, 1999 • 8 p.m. on PBS (CHECK LOCAL LISTINGS)

HOW DO BEES AND OTHER INSECTS fly? The answer is not as straightforward as you might think. As you see in this episode of SCIENTIFIC AMERICAN FRONTIERS, scientists at Cambridge University in England developed this large-scale mechanical model of a hawkmoth to learn more about how insects' tiny wings can produce enough lift to keep their heavy bodies airborne. Tune in to **Life's Little Questions** for more fascinating answers about how things work.

NOTE: The order of the activities in this guide does not reflect the actual order of the stories in this show. The actual order of the stories in the show is as follows:

1. "Why Are Peppers Hot?"
2. "Can You Beat Jet Lag?"
3. "How Do Bees Fly?"
4. "Why Does Traffic Jam?"
5. "Sand to Nuts"

SCIENTIFIC AMERICAN FRONTIERS is made possible by an underwriting grant from GTE Corporation. The series is produced by The Chedd-Angier Production Company in association with *Scientific American* magazine and presented to PBS by Connecticut Public Television. Classroom materials produced by Media Management Services, Inc.

GTE

5 WHY ARE PEPPERS HOT?

Paradoxically, the same compound that makes chile peppers hot also relieves pain. For some patients, it's a medical breakthrough.

RUNNING TIME: 14:35

ACTIVITY: Are you a supertaster?

6 HOW DO BEES FLY?

Bees, flies and other insects should not be able to fly, according to conventional rules of aerodynamics. And yet they do. Find out why.

RUNNING TIME: 9:51

ACTIVITIES: Build a wind tunnel. . . . Test models

8 CAN YOU BEAT JET LAG?

Travelers and night workers would love to be able to reset their biological clocks. They can, with an unusual application of light.

RUNNING TIME: 6:37

ACTIVITY: Raise mealworms in light and dark

9 WHY DOES TRAFFIC JAM?

Physics provides an explanation to those traffic problems that seem to arise out of nowhere. And computer simulations will tell us even more.

RUNNING TIME: 10:43

ACTIVITY: Modeling impact waves

10 SAND TO NUTS

Seemingly trivial questions about coffee spills, mixed nuts and sand lead to complex, intriguing areas of study and further inquiry.

RUNNING TIME: 10:52

ACTIVITIES: Study coffee stains, sand and nuts

Plus, in every issue . . .

4 VIEWER CHALLENGE

Guided viewing quiz questions, T-shirt prizes!

11 FRONTIERS ONLINE

Visit us at www.pbs.org/saf/

Looking for more information on how SCIENTIFIC AMERICAN FRONTIERS programs and activities correlate with education standards being used in your school district? PBS Online offers a new searchable database with links to the National Science Education Standards, plus state standards and other subject area standards. Visit www.pbs.org/teachersource/findit.html and type "Scientific American Frontiers" (in quotes) in the keyword search field. Or search by grade level or subject area to find the standards correlations you're looking for.

You'll find fascinating articles in each issue of *Scientific American* magazine, with multiple links to episodes of FRONTIERS. To subscribe, write to:
Scientific American, Dept. SAF, 415 Madison Ave., New York, NY 10017.
A one-year subscription costs $24.97.

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

BIOLOGY/LIFE SCIENCE: evolution, nervous system, plants
CHEMISTRY
GENETICS
HEALTH: disease
SOCIAL STUDIES: geography

SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8: Structure and Function in Living Systems, Reproduction and Heredity, Diversity and Adaptations of Organisms; **9-12:** Biological Evolution, Interdependence of Organisms, Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Personal Health, Science and Technology in Society; **9-12:** Personal and Community Health, Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

BIOLOGY/LIFE SCIENCE: insects, plants
PHYSICAL SCIENCE/PHYSICS: flight aerodynamics
TECHNOLOGY: engineering design, wind tunnels

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8, 9-12: Motions and Forces / **LIFE SCIENCE: 5-8:** Structure and Function in Living Systems, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** Biological Evolution, Behavior of Organisms / **EARTH AND SPACE SCIENCE: 5-8:** Structure of the Earth; **9-12:** Origin and Evolution of the Earth System / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8, 9-12:** Science as a Human Endeavor

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

BIOLOGY/LIFE SCIENCE: biological clock, nervous system
HEALTH: sleep
PSYCHOLOGY: circadian rhythms
TECHNOLOGY

SCIENCE AS INQUIRY / LIFE SCIENCE: 5-8: Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9-12:** The Cell, Biological Evolution, Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Personal Health, Science and Technology in Society; **9-12:** Personal and Community Health, Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

COMPUTER SCIENCE
EARTH SCIENCE: impact craters
PHYSICAL SCIENCE/PHYSICS: impact waves
TECHNOLOGY: engineering design

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8, 9-12: Motions and Forces / **EARTH AND SPACE SCIENCE, 5-8:** Earth in the Solar System; **9-12:** Origin and Evolution of the Universe / **SCIENCE & TECHNOLOGY: 5-8, 9-12:** Abilities of Technological Design / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Natural Hazards, Science and Technology in Society; **9-12:** Natural and Human-induced Hazards, Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

CHEMISTRY
MATERIALS SCIENCE
PHYSICS/PHYSICAL SCIENCE: granular particles
TECHNOLOGY

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5-8: Properties and Changes of Properties in Matter; Structure and Properties of Matter / **SCIENCE & TECHNOLOGY, 5-8, 9-12:** Abilities of Technological Design, Understandings About Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5-8:** Science and Technology in Society; **9-12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5-8:** Science as a Human Endeavor, Nature of Science; **9-12:** Science as a Human Endeavor, Nature of Scientific Knowledge, Historical Perspectives

FREE TAPING RIGHTS

- ✔ As a teacher, you have free off-air taping rights in perpetuity for classroom use.
- ✔ Always check TV listings to confirm air date and time.
- ✔ If you can't find the show in your TV listings, call your local PBS station.
- ✔ Educators may photocopy all materials in this guide for classroom use.
- ✔ Do you need help? Call the FRONTIERS School Program at 800-315-5010.
- ✔ Videotapes of past shows can be purchased ($21.97 each). Call 800-315-5010.

LET US HEAR FROM YOU!

Do you have a comment or question about FRONTIERS? Do you know someone who wants to sign up for free teaching materials? PLEASE CONTACT US . . .
BY MAIL: SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425 • PHONE: 800-315-5010 • FAX: 215-579-8589 • E-MAIL: saf@pbs.org

SCIENTIFIC AMERICAN FRONTIERS is closed-captioned for the hearing-impaired and is narrated by Descriptive Video Service (DVS) for visually impaired audiences. The series and School Program are endorsed by the National Science Teachers Association (NSTA) and the National Education Association (NEA).

VIEWER CHALLENGE

Life's Little Questions

SCIENTIFIC AMERICAN FRONTIERS

Show 904 • February 24, 1999, at 8 p.m. on PBS (CHECK LOCAL LISTINGS)

Watch SCIENTIFIC AMERICAN FRONTIERS for answers to the questions on this page.
Answer the 10 questions correctly and you'll be eligible to win a FRONTIERS T-shirt!

Reminder: Cover the answer key at the bottom of this page before photocopying.

Student's Name: _____

Teacher's Name & Course: _____

Why Are Peppers Hot?

1. Among the general population, about how many people are supertasters?
   - ☐ a. 1 in 6
   - ☐ b. 1 in 3
   - ☐ c. 1 in 10
   - ☐ d. 1 in 4
2. Capsaicin, the compound found in peppers, relieves pain because it:

   _____

   _____

Can You Beat Jet Lag?

3. When a person's biological clock is reset, this hormone is affected:
   - ☐ a. estrogen
   - ☐ b. insulin
   - ☐ c. melatonin
   - ☐ d. testosterone
4. In humans, the biological clock can be reset by:

   _____

   _____

How Do Bees Fly?

5. According to conventional laws of aerodynamics, bees should not generate enough lift to fly. What are two reasons they should not be able to fly?

   _____

   _____

6. On insects, halteres evolved from a second set of wings and act as:
   - ☐ a. airfoils
   - ☐ b. gyroscopes
   - ☐ c. spoilers
   - ☐ d. rudders

Why Does Traffic Jam?

7. What are two ways city planners can use information from traffic simulations?

   _____

8. The actual name for the phenomenon that explains mysterious traffic jams caused by one car slowing down is:

   _____

Sand to Nuts

9. How do grains of sand behave when they first begin to move?
   - ☐ a. They move slightly apart.
   - ☐ b. They move up.
   - ☐ c. They move down.
   - ☐ d. They move sideways.
10. When coffee spills on a flat surface, where are most of the particles deposited as the liquid evaporates?

    _____

    _____

Ask a friend or family member to think of a "little question" (other than one featured on the show). Then become a scientist and look for the answer! You may use any reference materials you wish, as well as your own critical thinking skills. In an essay of 100 words or less, describe how you went about finding the answer to the question and make a theory based on your research. Send your essay to Extra Credit Contest at the address to the right. If your essay is selected to appear on the FRONTIERS website, you'll win a FRONTIERS T-shirt. ***Good luck!***

FOR TEACHERS ONLY

When completed, this page can become an entry to the FRONTIERS T-shirt contest; 20 winners (10 students, 10 teachers) will be drawn at random for each show. To enter the T-shirt drawing, send all completed challenges in one envelope with a cover sheet to: Viewer Challenge, SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425. Mail completed entries by **March 26, 1999.**

TIP: You can download these questions at www.pbs.org/saf/questions.html (click "Teaching Guide").

IMPORTANT!! Please include a separate cover sheet and tell us:

- number of challenges submitted
- teacher's name
- grade and course
- school name, address and phone number
- where your students watched the show — at home, at school or both
- the name of your students' favorite story in this show (conduct a quick poll to find out)

Thank you!

Answers to the Viewer Challenge: 1. d 2. a. light or eyes or b. light or flower 3. c 4. any two of: long face too small, large face too closely, 5. b 7. new traffic lights, new highways, new tunnel borders or exclusion 8. Standard jumpstarting term 9. a 10. around the edges of the stain

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WHY ARE PEPPERS HOT?

Chile peppers are notoriously hot. But does anyone know why? Food researchers explain it's the capsaicin in the peppers that makes them hot. Recently, scientists were surprised to discover that capsaicin is also the source of a medical breakthrough, seen here on TV for the first time. Paradoxically, what makes peppers burn can also bring relief from pain — under the right circumstances.

Genetics of Taste

Does broccoli taste bitter? Is eating hot peppers intensely painful? Scientific evidence suggests a genetic basis for food preferences — and it's all on the tip of the tongue. Infants are born with a genetically determined number of taste buds. Some have only a few hundred, while others have tens of thousands per square centimeter.

The mushroom-shaped structures on the tip of your tongue are called fungiform papillae. Each contains about a half dozen taste buds. Other bumps on the tongue are different kinds of papillae that do not contain taste buds.

Linda Bartoshuk, seen on FRONTIERS, is professor of surgery and taste researcher at Yale University School of Medicine. She divides people into three groups: supertasters (25% of the population), medium tasters (50%) and nontasters (25%). According to her research, supertasters have many more taste buds per square centimeter, which enables them to experience the taste, temperature and texture of foods more keenly than nontasters.

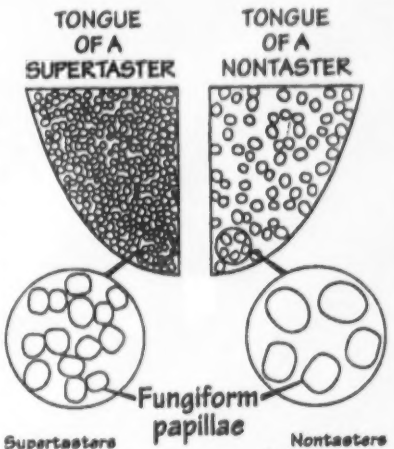
Of all the senses, taste is the least understood. We do know that smell is closely associated with taste. In the 1930s, researchers accidentally discovered a chemical substance that was tasteless to about 25% of people and bitter to the other 75%. Today's genetic studies continue to provide more data about the complex sense of taste.

SEE PAGE 11

Linda Bartoshuk of Yale Medical School answers your questions online. www.pbs.org/saf/questions.html

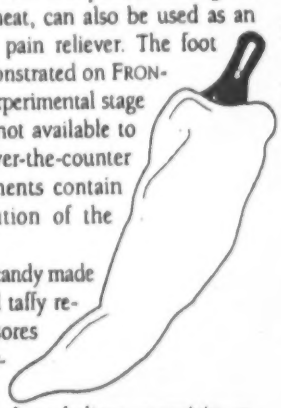
Are You a Supertaster?

Here's a simplified adaptation of Bartoshuk's taster test you could try at home, using blue food coloring and a plastic reinforcement ring for a three-hole binder (paper reinforcement rings get mushy). Use a cotton swab to wipe some blue food coloring on the tip of your tongue. Place the ring on your tongue. If you are a medium taster, you'll see only a few little "mushrooms" inside the ring's opening. If you're a supertaster, you'll find more than 25 of them within the circle. How many do you count?


TONGUE OF A SUPERTASTER
TONGUE OF A NONTASTER
Fungiform papillae
Supertasters have more papillae that are very closely arranged and smaller.
Nontasters have fewer papillae that are loosely arranged and larger.

Capsaicin Pain Relief

Taste researchers have recently discovered that capsaicin, the component that gives peppers their heat, can also be used as an anesthetic and pain reliever. The foot treatment demonstrated on FRONTIERS is in an experimental stage of testing and not available to the public. (Over-the-counter gels and ointments contain a weaker solution of the chemical.)



Hot pepper candy made with chiles and taffy relieves mouth sores of people undergoing chemotherapy. Researchers believe capsaicin reduces substance P, a neurotransmitter that carries pain messages to the brain. To learn more, visit:

oncolink.upenn.edu/cancer_news/1994/hot_candy.html

When handling hot chiles, wear rubber gloves and do not touch your lips or eyes.

QUESTIONS

1. What might be some evolutionary advantages to being a supertaster – for animals and humans?
2. What other factors might explain a person's food preferences?
3. Supertasters find coffee and cruciferous vegetables (broccoli, cabbage) too bitter, and sugary foods sickeningly sweet. Supertasters can also detect gradations in fat; for example, they can taste the difference between skim and whole milk. Using these findings, design a taste-testing experiment to identify supertasters.
4. Columbus and other explorers introduced peppers to the rest of the world, along with other New World foods like potatoes and tomatoes. Research different kinds of peppers used in cuisines throughout the U.S. and the world. What peppers are grown in your area or available at local markets?
5. All peppers are rated on a heat scale (bell peppers are zero). Look up the ratings at:

www.wiw.org/~corey/chile/scoville.html

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SCIENTIFIC AMERICAN FRONTIERS

HOW DO BEES FLY?

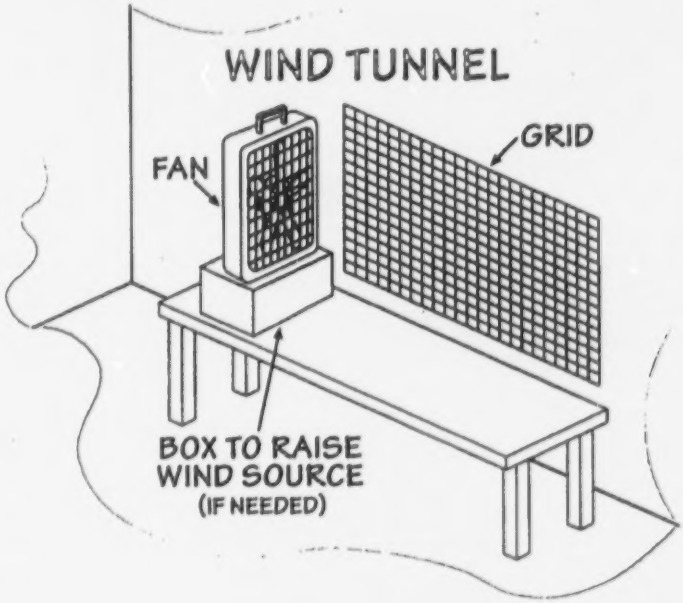
According to the laws of aerodynamics used by airplane engineers, bees and other insects should not be capable of flight. And yet many insect species have been flying for over 300 million years. So how do they do it? FRONTIERS travels to Cambridge, England, and the University of California at Berkeley in a quest to find out. One of the answers involves a vestigial pair of wings.

Blowing in the Wind

Insects defy all the rules of aerodynamics. Scientists have questioned how bees, flies, moths and other insects achieve sufficient lift to fly. How can such tiny wings lift relatively heavy bodies?

Scientists you meet on FRONTIERS build wind tunnels and utilize high and low technology as they explore the complexities of insect flight. Biologist Charles Ellington of Cambridge studies hawkmoths in his wind tunnel. Biologist Michael Dickinson at Berkeley uses a video-enhanced wind tunnel to find out how diminutive Drosophilas (fruit flies) can be so acrobatic.

Aircraft engineers use wind tunnels to test airplane design and efficiency. In this activity, you'll build a simple wind tunnel to help formulate and answer questions about how wind influences animals and plants.



Build a Wind Tunnel

MATERIALS:

- ☐ wind tunnel: 14" fan, boxes
- ☐ model wings: pencil, cardboard, tape
- ☐ various plants for testing
- ☐ optional: video camera, large sheets of paper

PROCEDURE

1. Set up your wind tunnel on a table or counter near a wall, as shown above. The table should be at least three feet long.
2. Place a fan on one end of the table so that the wind is directed toward the other end. A circular or box fan at least 14" in diameter with three variable speeds works best. You may wish to use different sized cardboard boxes to vary the height of your wind source.
3. Optional: On a large sheet of paper, at least 60cm high by 90cm long, draw a grid with 4cm squares. You may vary this grid based on the overall dimensions of your wind tunnel. The grid will allow you to measure changes in objects you place in your wind tunnel by using a video camera and image analysis.

EXTENSIONS

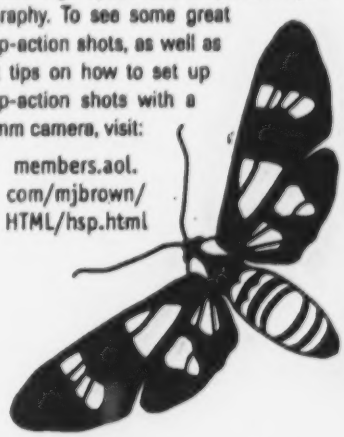
1. The wind tunnel described here is a simple version. You'll find other plans for building wind tunnels and activities at these websites:

   observe.ivv.nasa.gov/nasa/aero/tunnel/tunnel_ed.html

   ldaps.ivv.nasa.gov/Curriculum/tunnel.html

2. The research on flies you see on FRONTIERS utilizes high-speed and stop-action photography. To see some great stop-action shots, as well as get tips on how to set up stop-action shots with a 35mm camera, visit:

   members.aol.com/mjbrown/HTML/hsp.html



SEE PAGE 11

Michael Dickinson and Claire Balint of University of California, Berkeley answer your questions online.
www.pbs.org/saf/questions.html

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Testing Model Wings

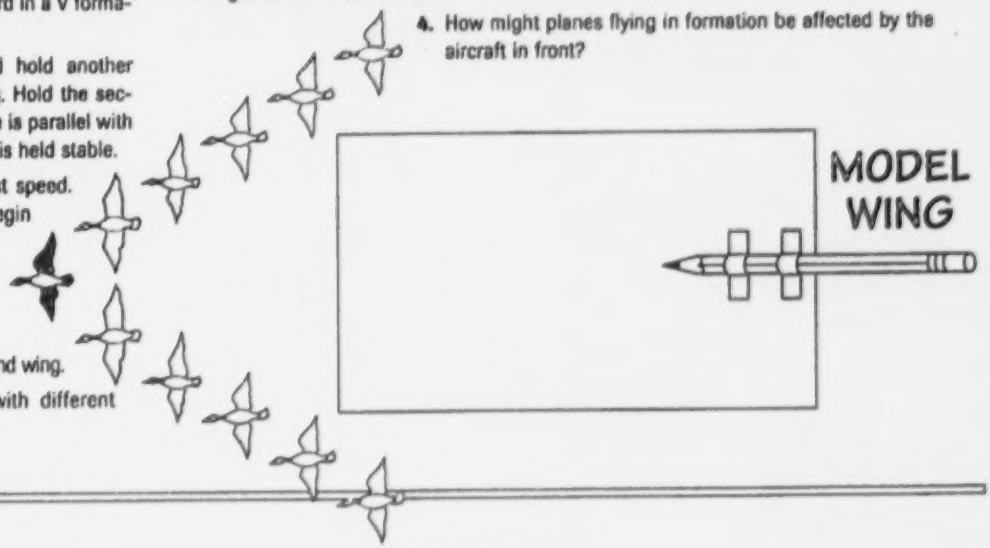
Use the wind tunnel to explore why geese fly in formation.

PROCEDURE

1. Make two or more model geese wings by attaching cardboard to a pencil with tape. (See drawing of model wing.)
2. One student should hold one wing approximately 30cm away from the fan, to simulate the wing of the lead bird in a V formation of migrating geese.
3. A second student should hold another wing behind the first wing. Hold the second wing so its flat surface is parallel with the plane of the table and is held stable.
4. Turn the fan on the lowest speed. The first student should begin slowly flapping the lead wing up and down.
5. As the first wing is moved up and down, observe the effect on the second wing.
6. Repeat the experiment with different wind speeds.

QUESTIONS

1. What effect did flapping the first wing have on the second wing at low wind speeds? Higher wind speeds?
2. What advantage do you think a bird second in line might have? For example, do you think it might use less or more energy? Defend your answer with your observations from the wind tunnel.
3. How can you improve this model of birds in flight to be more accurate?
4. How might planes flying in formation be affected by the aircraft in front?



Testing Plants

Use the wind tunnel to examine why certain plants do not break in strong winds.

1. Obtain samples of different potted plants or trees. Plants should be small enough to place in your wind tunnel or sit at the end of the table so the leaves are placed in the path of the wind.
2. Place a plant sample in your wind tunnel. Sketch the shape of the plant before the fan is turned on. (If you have a video camera, you may want to use it to record the experiment.)
3. Turn the fan on its lowest setting. Record any changes in the shape of the entire plant. Also, write down any interesting observations you can see for individual stems or leaves. For example, do leaves stay rigid or turn in the wind?
4. Increase the speed of the wind and record any changes you observe.

QUESTIONS

1. How did the shape of the plant change as wind speed increased? Did the shape become more aerodynamic?
2. How might the change of shape, or lack of change, help protect the plant during high winds?
3. Based on your observations, do you think the plants you tested are adapted to habitats that experience high winds? Explain why or why not.
4. What other adaptations might help plants to survive in areas with very strong winds?

EXTENSIONS

1. Nonliving components of nature are also subject to the wind. Design an experiment to answer the question: How are sand dunes formed?
2. Extend your sand dune experiment to ask: How do plants help stabilize sand dunes?

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SCIENTIFIC AMERICAN FRONTIERS

CAN YOU BEAT JET LAG?

Attempts to fool our bodies into beating jet lag have created entire industries. The scientific explanation involves light and hormones. Alan Alda finds out as he subjects himself to a sleep experiment that the ultimate solution to resetting the human biological clock is not quite as easy as it might appear. But the findings could have useful applications to millions of troubled sleepers.

Hey, Turn Out the Light!

If you've ever traveled across time zones and felt disoriented during and after your travels, you've probably experienced jet lag. Evolution hasn't caught up with our modern lives. Science tells us that all animals and plants have a biological clock that does not quite match our clocks and calendars. For most people, the natural internal clock follows a cycle that is about 30 minutes longer than the planetary day/night cycle.

As you see on FRONTIERS, upsetting the human biological clock can have significant effects on the body. Other animals also have a biological clock that is set for a "normal" day of light and dark cycles.

In this activity, you'll test the effect of light on the development of mealworm larvae into adults.

If you cannot conduct a long-term experiment with mealworms, how else could you test the effects of light on other animals, such as cats, hamsters, dogs, birds or fish? Design your own experiment and give it a try!

MATERIALS

- ☐ plant grow light and timer
- ☐ king mealworms (may be purchased at a bait or pet store)

PROCEDURE

Mealworms take a week or more, depending on variables, to reach the pupa stage and another week to hatch into adult beetles when kept in covered containers and at room temperature. In this experiment you will subject two populations of mealworms to different cycles of light and dark to see if changing the normal cycle speeds up this development. Development in insects is subject to temperature, so mealworms need to be kept at the same temperature.

1. Obtain two containers of mealworms for use in this experiment. Make sure each container has the same number of mealworms (transfer mealworms from one container to another if necessary to equalize the population). Record the number of larvae in each container.
2. Enclose one container of mealworms in a box in your classroom that is not directly in the sun. (**NOTE:** Make sure each container is kept at room temperature to minimize temperature as a variable.)
3. For the second mealworm container, set up a grow light with a timer. Set the timer for twelve hours of light and twelve hours of darkness. This group should be covered so the only light they receive is from the grow light. (See drawing for setup.)
4. Each day, note any changes you observe in your mealworm population. Be sure to record the total number of adult beetles versus larvae in your data table.
5. As adults appear, remove them from the container so they do not interfere with the development of the larvae. Continue to record data until all the larvae have turned into adults. (You can release the grown beetles outside or use them as food for reptile pets.)

QUESTIONS

1. Did the grow light seem to affect the development of the larvae into adults?
2. Do you think there is an "optimal" amount of light versus dark to speed up the development of the larvae? Design an experiment to prove or disprove your theory.

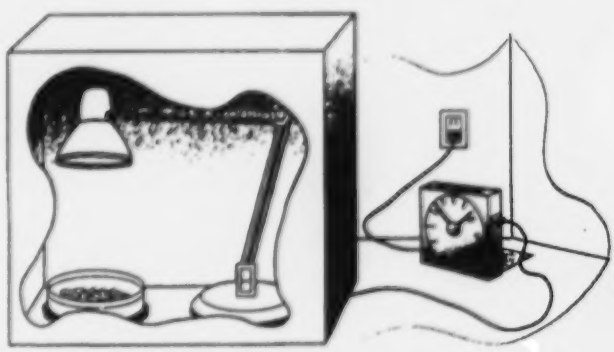
EXTENSIONS

1. Studies have shown that age may influence what time of day people are most active. Design a questionnaire to find out what time of day students like to wake up and what time of day they feel they can get the most work done. How do the answers vary? Research the efforts of some school districts to change the hours of the school day.
2. With your teacher's permission, interview people who work nights (police, reporters, grocery store clerks, factory workers) to see how they adjust to working at night and if they consider themselves a night or day person and why.
3. Take part in the online science experiment in biological timing and find out more at:

   www.cbt.virginia.edu/Olh
4. Investigate circadian rhythms and the effects of light in people who are blind.

SEE PAGE 11

Scott Campbell and Patricia Murphy of Cornell University Medical College answer your questions online.
www.pbs.org/saf/questions.html



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WHY DOES TRAFFIC JAM?

Ever wonder why traffic sometimes piles up for no reason? The FRONTIERS crew travels to Los Alamos to investigate this question. Physics and high-tech traffic simulations on supercomputers provide the answers. Simulation is used to understand traffic patterns and design more efficient, workable roads. In fact, a project in Oregon is attempting to simulate an entire city and its population.

Modeling Impact Waves

As you see in this episode of FRONTIERS, some traffic jams can be explained by what traffic engineers call a "backward propagating wave." A propagating wave disperses its energy across a medium. As the wave disperses, it continues to spread out. In the traffic example, when one car slows down momentarily, it creates a backward wave that affects the cars behind it.

When scientists want to study events that cannot be duplicated in a laboratory (like a traffic jam), they must create simulations that can be controlled and repeated to discover predictable theories or laws. Computers like those at Los Alamos are used to simulate events from nuclear wars to terrorist attacks and, now, traffic.

Scientists also needed to use models and simulations to research their theories about craters on the moon's surface. In this activity you will create a model to simulate the impact of a meteorite on a planet's surface.

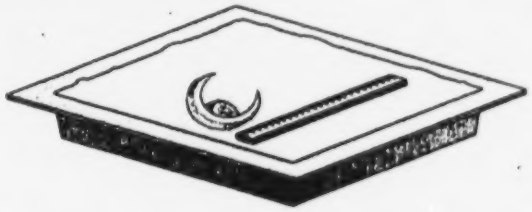
MATERIALS

- ☐ flour
- ☐ ruler
- ☐ large glass or foil cake pan
- ☐ several marbles of varying sizes
- ☐ colored powdered tempera or poster paint

NOTE: You may wish to conduct this activity outdoors.

SEE PAGE 11

Kaf Nagel and Chris Barrett of Los Alamos National Laboratory answer your questions online. **www.pbs.org/saf/questions.html**



PROCEDURE

PART 1: Does the size of the meteor make a difference on the impact?

1. Fill the cake pan with flour and pack it down somewhat.
2. Dust the surface of the flour with powdered tempera paint.
3. Predict what you think will happen if you drop a marble into the flour/paint mixture. Write your prediction on a piece of paper.
4. From a height of 1 meter above the pan, drop a marble into the flour/paint mixture.
5. Measure the diameter and the depth of the resulting crater.
6. Repeat steps 4 and 5 with marbles of varying sizes. Which marbles make the larger impact craters? Why?
7. Design a method for determining the size of waves sent out from the impact.

PART 2: Does the angle of impact make a difference on the crater?

In the early 20th century, it was thought that volcanoes, not meteors, had made the circular craters on the moon. Scientists theorized that by hitting the surface at an angle, meteors would leave an oblong rather than a circular crater. To test their theories, they made models. What do you learn from this miniature moon model?

1. Use the same pan of flour, again slightly packed and dusted with tempera paint.
2. This time you'll shoot the marbles at the flour mixture from different angles. Again, make a prediction of the outcome and write it down. Then shoot the marbles at the pan of flour at different angles.
3. Measure the diameters of the impact craters. What shapes are the impact craters? How do you explain their shapes?

QUESTIONS

1. Did the impact of the marble in the flour have any consequences other than the impact crater? Why would this be important for scientists to understand?
2. What type of wave is sent through the flour after the marble collides with the surface?

EXTENSIONS

1. The experiments you performed with the flour simulated the impact of a meteor hitting sand. Create other models to simulate other parts of the earth or planetary objects. Experiment with how a collision sends impact waves through other media (water, Slime, clay, a mud mixture, etc.).
2. The next time you're caught in a traffic jam, investigate the causes. Is it an example of a backward propagating wave?
3. You can simulate your own traffic jam at these websites:

lcs.www.media.mit.edu/groups/el/Projects/starlogo/projects/social.html

traffic.comphys.uni-duisburg.de/ca_model/simulation.html

ANSWERS: PART 2, Step 3: circular; although the object hits at an angle, the crevice made is round **Questions:** 1. yes; students should observe the flour being blown out and the waves created by the force of the marbles. They'd also be able to estimate the force of the impact. 2. longitudinal

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SAND TO NUTS

Footprints on the beach, a can of mixed nuts, sand in an hourglass and coffee spilled on kitchen counters may not seem like critical topics for study, but these same subjects have led scientists to some fascinating explorations into materials science. In this story, watch as seemingly trivial questions lead curious scientists into inspired investigations about much bigger issues.

Lessons Learned From Coffee

As you see in this episode of FRONTIERS, seemingly insignificant questions sometimes lead to complex answers — and to other questions.

Physicist Sidney Nagel of the Materials Center at the University of Chicago began his investigation by wondering about something we've all seen many times — coffee stains on a kitchen counter. His questions about why the stains form as they do became almost an obsession with scientists from several fields. Watch the program to find out what they discovered. Then try this simple experiment to learn more.

MATERIALS

- ☐ powdered tempera paints or other water colors (light colors work best)
- ☐ various liquids: coffee, salt water, tap water, soda, juice, Tang, tea, cocoa
- ☐ plastic lids from butter tubs, coffee cans, etc.
- ☐ paper, cloth and/or a flat, washable surface

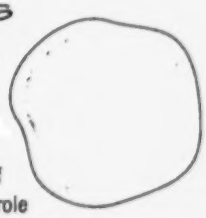
PROCEDURE

1. Mix the paint and any of the powdered drink mixes with water according to package directions.
2. Place several drops of paint and of each liquid onto paper, cloth or a flat surface.
3. Watch as the drops dry.
4. Write down your observations of the phenomenon. Note what changes occur every five minutes.

Now introduce some variables:

5. Place a few drops on paper and let it dry upside down. What happens?
6. Use plastic lids as covers to manipulate the evaporation of liquids. Make covers that will:
   - ☐ Completely cover the drop. What happens?
   - ☐ Cover the edges of the drop but expose the center. What happens?
   - ☐ Cover half of the drop and leave the other half exposed. What happens?

QUESTIONS



1. Which liquid(s) developed the most distinct ring(s)? The least? Why?
2. How did the rate of evaporation play a role in the formation of the ring?
3. How did the surface beneath the drops (paper or countertop) affect the rate of evaporation and the development of the deposition ring?

EXTENSIONS

1. Try the above experiment on pieces of paper with different textures: computer or notebook paper, construction paper or homemade recycled, paper towel, coffee filters, etc. Compare the results achieved by using these different surfaces.
2. Compare stains left by coffee made using different methods – instant, filtered, espresso, cappuccino. What accounts for the differences?
3. Watch a drop of coffee evaporate through a microscope. Explain what you see happening as the liquid evaporates.
4. Look up the chemical composition of caffeine and sketch an illustration.

Materials Science

Physicists Sidney Nagel and Heinrich Jaeger have made careers out of studying properties and behavior of various materials. As you see on FRONTIERS, their work sometimes takes them in unexpected directions. Try replicating some of the experiments you see on the program. What do you observe?

1. Next time you're on a beach, see if you can create a "halo" effect with your feet.
2. Put some sand and water in a squeeze bottle. Do you get the same results seen on the show?
3. Find a clear plastic tube. Put some sand and a small ball in it. Can you get the ball to climb to the top of the tube? Can your friends do it? (Try testing people who haven't watched this episode of FRONTIERS.)
4. Obtain a can of mixed nuts. How are the nuts mixed when the can is first opened? Shake the can. How do the nuts mix or unmix? Do you think it would be possible to design a can that keeps the nuts evenly mixed? Explain. (**HINT:** if nuts are shaken many times, the walls of the can become so smooth that the nuts will no longer unmix. Friction is one key.)
5. You can learn more about the experiments with coffee and other materials at the Materials Center of the University of Chicago. You'll also learn more about practical applications of these findings. To learn more, visit:

   mrsec.uchicago.edu/MRSEC/

SEE PAGE 11

Sidney Nagel and Heinrich Jaeger of University of Chicago answer your questions online.
www.pbs.org/saf/questions.html

Answers: 1. liquids that are partially wetting and volatile should cause rings (coffee, Kool-Aid, salt water, soda); 2. as the liquid evaporates from the drop, molecules of evaporating liquid continually replenish the exterior of the drop; 3. answers will vary

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Galapagos Cyber Field Trip —You Can Relive It Online

On December 6, 1998, thousands of teachers, students and SCIENTIFIC AMERICAN FRONTIERS fans embarked on a once-in-a-lifetime expedition — a week-long cyber field trip to the Galapagos Islands! By logging on to a special section of the FRONTIERS website on PBS Online designed especially for the trip (www.pbs.org/saf/galapagos.html), visitors joined Alan Alda, the FRONTIERS crew, a group of scientists and two School Program ambassadors — Sherri Steward, a high school teacher from Texas, and Mandy Williams, a college biology student — for an exciting learning experience made possible by the series underwriter, GTE Corporation.

The expedition was a phenomenal success! Science classrooms around the globe experienced the beauty and wonder of the Galapagos Islands through the eyes and ears of Sherri and Mandy. With the help of Andy Liebman of the Chedd-Angier Production Company (which produces the FRONTIERS series), the resourceful pair transmitted vivid photos, captivating videos and engaging narratives of their adventures to the School Program staff back home. Thanks to their hard work, legions of "expedition mates" were able to appreciate sights they may never see firsthand — majestic Galapagos tortoises, feisty marine iguanas, a bird species named for Charles Darwin himself, cacti flourishing alongside a Pacific beach and lava formations unlike any others on Earth.

If you and your students were unable to participate in this live event, don't despair. The entire "Destination: Galapagos Islands" website will remain permanently archived on PBS Online. Students can read the Q&As between other students and Sherri, Mandy, naturalist Lynn Fowler and scientists Martin Wikelski and David Anderson. Classrooms can conduct interactive experiments directly related to scientific research in the Galapagos. Teachers can find classroom activities and link to resources for further information. And best of all, everyone can watch as a Galapagos mockingbird perches fearlessly on Sherri's arm, a friendly tortoise poses for a photo with Mandy and Alan snorkels with some curious sea lions!

This male frigate bird — a Galapagos Islands native — displays his bright plumage to attract female frigates.

Thanks to all who participated in the "Destination: Galapagos Islands" cyber field trip. Don't forget to tune in to PBS next season for the FRONTIERS special on the Galapagos Islands that was filmed during the expedition!

Explore Life's Little Questions with FRONTIERS Online!

ASK THE Scientists Online

After **Life's Little Questions** airs, specialists from the show will answer questions about their work. The scientists featured below will be available from February 24 to March 12, 1999. To participate in Ask the Scientists, visit FRONTIERS online at www.pbs.org/saf/questions.html.

WHY ARE PEPPERS HOT?

Linda Bartoshuk of Yale Medical School answers your questions about capsicums (peppers), our response to their heat – and their potential as analgesics.

CAN YOU BEAT JET LAG?

Scott Campbell and Patricia Murphy of Cornell University Medical College tell you more about their surprising solution to reset our biological clocks.

HOW DO BEES FLY?

Ask Michael Dickinson and Clare Balint of the University of California at Berkeley about their research into the fruit fly's extraordinary feats of locomotion.

WHY DOES TRAFFIC JAM?

Ask Kai Nagel and Chris Barrett what their research at the Los Alamos National Laboratory reveals about a question that perplexes every driver.

SAND TO NUTS

Sidney Nagel and Heinrich Jaeger give you a report from the University of Chicago, where their research with grains of sand helps explain how particles move.

HOW TO "ASK THE SCIENTISTS"

Visit SCIENTIFIC AMERICAN FRONTIERS on PBS Online at www.pbs.org/saf/questions.html. Click on "Ask the Scientists" to send your question(s). Scientists' answers will be posted online for FRONTIERS viewers to read.

Remember to e-mail your questions by March 12, 1999!

PBS online

NOTE: AVAILABILITY OF SCIENTISTS IS SUBJECT TO CHANGE. DEPENDING ON VOLUME OF QUESTIONS RECEIVED, ONLY SELECTED QUESTIONS MAY BE ANSWERED.

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SCIENTIFIC AMERICAN FRONTIERS

Watch It On PBS

SCIENTIFIC AMERICAN FRONTIERS airs on PBS with five new programs each season, October through April. Each hour-long special includes a variety of intriguing science stories based on a single theme. Check local listings or the schedule on the FRONTIERS website (www.pbs.org/saf/) to find FRONTIERS programs airing in your area.

SHOW 901: Science in Paradise

***INTERNATIONAL SPECIAL!* WEDNESDAY, OCTOBER 7, 1998**

Dive into the beautiful waters of the Caribbean and find out what scientists are learning about the science of paradise.

SHOW 902: Journey to Mars

WEDNESDAY, NOVEMBER 11, 1998

3 . . . 2 . . . 1 . . . Blast off to Mars! Sometime early in the next century, humans may take off on the first manned mission to the red planet. Learn about scientists' exciting projects, from inflatable habitats to the search for Martian life.

SHOW 903: Animal Einsteins

WEDNESDAY, JANUARY 20, 1999

Dr. Dolittle isn't the only person who talks to the animals. Scientists tell us we can learn much from our furry, feathered and finned friends.

THIS ISSUE SHOW 904: Life's Little Questions

WEDNESDAY, FEBRUARY 24, 1999

What makes hot peppers hot? Why do traffic jams happen? What's the best way to combat jet lag? Join host Alan Alda in a scientific quest to answer some of the little questions that affect us, sometimes in big ways.

SHOW 905: Spiders!

WEDNESDAY, APRIL 21, 1999

Meet just a few of the 39,000 known spider species — including the world's largest, a 10-inch tarantula, and a cyberspider that lives inside a computer. And, learn about a 20th-century solution to an ancient fear, arachnophobia.

FILMING THIS EPISODE of SCIENTIFIC AMERICAN FRONTIERS, host Alan Alda visited the office of physicist Sidney Nagel — one of the best places to learn about the bizarre properties of everyday stuff. Join Alan and the FRONTIERS crew on their quest for the answers behind some of **Life's Little Questions**.

SEE IT ON PBS

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SCIENTIFIC AMERICAN FRONTIERS

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LIFE'S LITTLE QUESTIONS
AIR DATE:
February 24, 1999

PRINTED ON RECYCLED PAPER

SCIENTIFIC AMERICAN FRONTIERS

TEACHING GUIDE FOR SHOW 905
APRIL 21, 1999 - 8-9 P.M.

1998-99 Season Index inside!

Spiders!

A PBS SPECIAL

Hosted by Alan Alda

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SCIENTIFIC AMERICAN FRONTIERS

Show 905: Spiders!

April 21, 1999 • 8 p.m. on PBS (CHECK LOCAL LISTINGS)

THIS GARDEN CROSS SPIDER *(Araneus diadematus)* weaves an orb-shaped web to catch its prey. Orb webs are the beautiful spiral-shaped webs you may see in early morning hours, when nighttime moisture suspended from the web's strands makes it easier to spot. The garden cross spider is just one of the species you'll meet in this episode of SCIENTIFIC AMERICAN FRONTIERS, dedicated to Spiders!

ON THE COVER: *Megaphobema velvetosoma* female at her burrow in the rain forest of Iquitos, Peru. This tarantula was photographed by spider expert Rick West, who appears in this episode to introduce viewers to several tarantulas — including a newly discovered species named after host Alan Alda.

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GTE

5 SPIN, SPIN, SPIN . . .

Digital spiders that live inside computers can tell us much about when and how spiders spin webs, and how their webs might have evolved.

RUNNING TIME: 10:38

ACTIVITIES: Model an orb-weaver's web . . . Test web models in a web research lab

7 SONG AND DANCE

Meet Portia, a stealthy jumping spider that sends out deceptive signals to fool the enemy.

RUNNING TIME: 9:14

ACTIVITIES: Investigate spiders found in your neighborhood . . . Calculate population data

8 SPIDER CANYON

Scientists may be on the verge of witnessing the evolution of a new species among funnel-web spiders in Arizona.

RUNNING TIME: 12:10

ACTIVITIES: Create spider trading cards . . . Find out more about spiders

9 AMAZON TALES

Travel along a river in Ecuador, where spiders live in colonies. Meet a variety of tarantulas, including a new species named for Alan Alda.

RUNNING TIME: 10:33

ACTIVITY: Design a spider and select its adaptations

10 ARACHNOPHOBIA

Find out how science is treating arachnophobia, an ancient fear, with 20th-century virtual reality.

RUNNING TIME: 9:24

ACTIVITY: Spider Jeopardy!

Plus, in every issue . . .

4 VIEWER CHALLENGE

Guided viewing quiz questions, T-shirt prizes!

11 FRONTIERS ONLINE

Visit us at www.pbs.org/saf/

Give us your opinion about SCIENTIFIC AMERICAN FRONTIERS *and you may win a coveted* FRONTIERS *T-shirt! We've posted a new viewer survey on the* FRONTIERS *website (www.pbs.org/saf/), with a special area just for teachers. We want to know what you think!*

While you're logged on, be sure to sign up for FRONTIERS' *online mailing list. You'll receive program news and updates by e-mail. What could be easier? Don't forget, the* FRONTIERS *website also includes a complete broadcast schedule, a special area just for teachers, contests for your students and more. See you on the Web!*

You'll find fascinating articles in each issue of *Scientific American* magazine, with multiple links to episodes of FRONTIERS.
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BIOLOGY/LIFE SCIENCE: arachnids, diversity, evolution, invertebrates
CHEMISTRY: spider silk
COMPUTER SCIENCE
GENETICS
PHYSICAL SCIENCE: tensions & forces
TECHNOLOGY: computer modeling

SCIENCE AS INQUIRY / PHYSICAL SCIENCE: 5–8, 9–12: Motions and Forces / **LIFE SCIENCE: 5–8:** Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9–12:** Molecular Basis of Heredity, Biological Evolution, Behavior of Organisms / **SCIENCE & TECHNOLOGY: 5–8, 9–12:** Abilities of Technological Design, Understanding About Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5–8:** Science and Technology in Society; **9–12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5–8:** Science as a Human Endeavor, Nature of Science; **9–12:** Science as a Human Endeavor, Nature of Scientific Knowledge

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BIOLOGY/LIFE SCIENCE: arachnids, diversity, evolution, invertebrates
CHEMISTRY: spider silk
GENETICS
PHYSICAL SCIENCE: vibrations
TECHNOLOGY

SCIENCE AS INQUIRY / LIFE SCIENCE: 5–8: Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Diversity and Adaptations of Organisms; **9–12:** Molecular Basis of Heredity, Biological Evolution, Behavior of Organisms / **SCIENCE & TECHNOLOGY: 5–8, 9–12:** Abilities of Technological Design, Understanding About Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5–8:** Science and Technology in Society; **9–12:** Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5–8, 9–12:** Science as a Human Endeavor

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

BIOLOGY/LIFE SCIENCE: adaptations, arachnids, diversity, invertebrates
EARTH SCIENCE: biomes
ENVIRONMENTAL SCIENCE: habitats
GENETICS

SCIENCE AS INQUIRY / LIFE SCIENCE: 5–8: Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Populations and Ecosystems, Diversity and Adaptations of Organisms; **9–12:** Molecular Basis of Heredity, Biological Evolution, Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5–8:** Populations, Resources and Environments; **9–12:** Population Growth, Natural Resources / **HISTORY & NATURE OF SCIENCE: 5–8:** Science as a Human Endeavor, Nature of Science; **9–12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

BIOLOGY/LIFE SCIENCE: arachnids, evolution, invertebrates
ENVIRONMENTAL SCIENCE: tropical forests
GENETICS
TECHNOLOGY

SCIENCE AS INQUIRY / LIFE SCIENCE: 5–8: Structure and Function in Living Systems, Reproduction and Heredity, Regulation and Behavior, Populations and Ecosystems, Diversity and Adaptations of Organisms; **9–12:** Biological Evolution, Interdependence of Organisms, Behavior of Organisms / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5–8:** Populations, Resources and Environments; **9–12:** Population Growth, Natural Resources / **HISTORY & NATURE OF SCIENCE: 5–8:** Science as a Human Endeavor, Nature of Science; **9–12:** Science as a Human Endeavor, Nature of Scientific Knowledge

CURRICULUM LINKS ····► NATIONAL SCIENCE EDUCATION STANDARDS

BIOLOGY/LIFE SCIENCE: arachnids
COMPUTER SCIENCE: virtual reality
HEALTH SCIENCE
PSYCHOLOGY: anxiety, fear, phobia
TECHNOLOGY

SCIENCE AS INQUIRY / LIFE SCIENCE: 5–8: Regulation and Behavior, Diversity and Adaptations of Organisms; **9–12:** Behavior of Organisms / **SCIENCE & TECHNOLOGY: 5–8, 9–12:** Abilities of Technological Design, Understanding About Science and Technology / **SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES: 5–8:** Personal Health, Science and Technology in Society; **9–12:** Personal and Community Health, Science and Technology in Local, National and Global Challenges / **HISTORY & NATURE OF SCIENCE: 5–8:** Science as a Human Endeavor, Nature of Science, **9–12:** Science as a Human Endeavor, Nature of Scientific Knowledge

FREE TAPING RIGHTS

- ✔ As a teacher, you have free off-air taping rights in perpetuity for classroom use.
- ✔ Always check TV listings to confirm air date and time.
- ✔ If you can't find the show in your TV listings, call your local PBS station.
- ✔ Educators may photocopy all materials in this guide for classroom use.
- ✔ Do you need help? Call the FRONTIERS School Program at 800-315-5010.
- ✔ Videotapes of past shows can be purchased ($21.97 each). Call 800-315-5010.

LET US HEAR FROM YOU!

Do you have a comment or question about FRONTIERS? Do you know someone who wants to sign up for free teaching materials? PLEASE CONTACT US . . .
BY MAIL: SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425 • PHONE: 800-315-5010 • FAX: 215-579-8589 • E-MAIL: saf@pbs.org

SCIENTIFIC AMERICAN FRONTIERS is closed-captioned for the hearing-impaired and is narrated by Descriptive Video Service (DVS) for visually impaired audiences. The series and School Program are endorsed by the National Science Teachers Association (NSTA) and the National Education Association (NEA).

VIEWER CHALLENGE

Spiders!

SCIENTIFIC AMERICAN FRONTIERS

Show 905 • April 21, 1999, at 8 p.m. on PBS (CHECK LOCAL LISTINGS)

Watch SCIENTIFIC AMERICAN FRONTIERS for answers to the questions on this page. Answer the 10 questions correctly and you'll be eligible to win a FRONTIERS T-shirt!

Student's Name: _____

Teacher's Name & Course: _____

Reminder: Cover the answer key at the bottom of this page before photocopying.

Spin, Spin, Spin . . .

1. Spiders "hear" with their:
   - ☐ a. ears.
   - ☐ b. legs.
   - ☐ c. antennae.
   - ☐ d. abdomen hairs.
2. The spiral part of a spider's web traps prey because it is:

   _____

Song and Dance

3. Portia spiders are able to communicate over webs by sending messages or signaling via:
   - ☐ a. vibrations.
   - ☐ b. pheromones.
   - ☐ c. deceptive flights.
   - ☐ d. electrical currents.
4. The female spider in the story is attracted to the way the male spider:

   _____

Spider Canyon

5. The female funnel-web spider identifies its prey by:

   _____

   _____
6. The hybrid offspring of the aggressive desert spiders and the timid river spiders seem to be:
   - ☐ a. unintelligent.
   - ☐ b. overly aggressive.
   - ☐ c. very timid.
   - ☐ d. confused.

Amazon Tales

7. The spiders Leticia Avilés studies in Ecuador are unusual because they:
   - ☐ a. are huge.
   - ☐ b. are extremely aggressive.
   - ☐ c. live very long lives.
   - ☐ d. live in colonies.
8. What natural defense do tarantulas use to irritate their enemies?

   _____

Arachnophobia

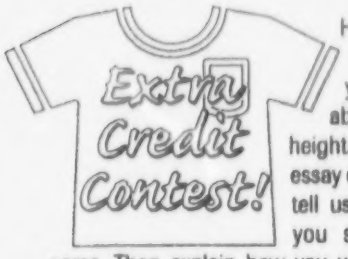
9. Identify three ways Joanne's fear or phobia of spiders affected her life:

   _____

   _____

   _____
10. Psychologist Al Carlin and scientist Hunter Hoffman used this technology to treat Joanne's phobia:

    _____



Have you ever had a phobia? Perhaps you were unreasonably afraid of spiders, heights or the dark. In an essay of 100 words or less, tell us about a fear that you successfully overcame. Then explain how you would advise others with the same phobia to conquer their fear. Send your essay by May 14, 1999, to **Extra Credit Contest** at the address to the right. If your essay is selected to appear on the FRONTIERS website, you'll win a FRONTIERS T-shirt. ***Good luck!***

FOR TEACHERS ONLY

When completed, this page becomes an entry to the FRONTIERS T-shirt contest; 20 winners (10 students, 10 teachers) will be drawn at random for each show. To enter the T-shirt drawing, send all completed challenges in one envelope with a cover sheet to: Viewer Challenge, SCIENTIFIC AMERICAN FRONTIERS, 105 Terry Drive, Suite 120, Newtown, PA 18940-3425. Mail completed entries by **May 14, 1999.**

TIP: You can download these questions at **www.pbs.org/saf/spiders.html** (click "Teaching Guide").

IMPORTANT!! Please include a separate cover sheet and tell us:

- number of challenges submitted
- teacher's name
- grade and course
- school name, address and phone number
- where your students watched the show — at home, at school or both
- the name of your students' favorite story in this show (conduct a quick poll to find out)

Thank you!

Answers to the Viewer Challenge: 1. b 2. sticky 3. a 4. characteristics/signals/behaviors (either this how spider looks) 5. sensing vibration patterns of prey landing on the web 6. b 7. d 8. releasing hairs that irritate skin 9. had to check the weather and dry/shed to leave house without checking for spiders/had to use duct tape around doors/had to clean her car and her house/could not go camping or outdoors 10. VR or virtual reality

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SPIN, SPIN, SPIN . . .

Danish arachnologist Fritz Vollrath studies spiders that exist only inside his computers. Vollrath's cyberspiders spin webs and even mate. By observing the behavior of these digital spiders, Vollrath is learning more about how and why spiders build webs. Watching successive generations of cyberspiders spin their webs is giving scientists an unexpected window into evolution.

What Webs We Weave

Like other spiders that weave webs, orb weavers are nearly blind. Despite their poor vision, they spin intricate, exquisite webs to trap their prey. To find out just how spiders plan and build their webs, arachnologist Fritz Vollrath programs digital spiders to simulate the behavior and web-building strategies of orb-weaving spiders in nature.

Researchers studying spider behavior often use orb-web spiders for their subjects. For example, scientists might watch as a spider builds a web in a frame, then turn the frame in another direction or upside-down to find out how the spider responds. Spiders have also accompanied astronauts on NASA flights to test the effects of microgravity on web-building.

Given the dexterity of your fingers and the fact that your vision is probably superior to that of a spider's, what kind of webs can you weave? In this activity, you'll build a model of a spider web.

MATERIALS

- ☐ string (about 300cm per web)
- ☐ 12" x 12" x ¼" wooden board
- ☐ 4 short nails

NOTE: Instead of building the web with nails, you might wish to experiment with using glue to attach the threads.

SEE PAGE 11

Fritz Vollrath of University of Aarhus in Denmark answers your questions online.
www.pbs.org/saf/spiders.html

PROCEDURE

1. CONSTRUCT THE FRAMEWORK THREADS (FIGURE 1):

   Two inches in from each corner, hammer nails into the board to serve as supports to which you'll attach the framework threads. Tie the beginning of your string to point A and pull it to point B. Wrap the string around point B and pull it to point C. Wrap the string around point C and pull it to point D. Wrap the string around point D and pull the string back to point A and tie a knot.

2. CONSTRUCT THE RADIAL THREADS (FIGURE 2):

   About two inches over from point A, tie a new length of string. Draw it across the framework and tie it to the framework thread diagonal to this point. This is the first radial thread. Tie another string in the center of the framework between points A and B. Draw it across to the opposite framework and tie it. Tie a third radial two inches left of point B and draw it across in a diagonal, crossing the first and second radials. Repeat these steps to lay down radials between points B and C. Lay down a total of six radials. Make sure radials meet in the center, or hub, of the web.

3. CONSTRUCT THE SPIRAL (FIGURE 3):

   Tie a new section of string to the center of the web. Loop it over and under each radial in a spiral, radiating out until you get to the framework. Tie the end of the spiral off at the framework. You may want to glue your spiral to the radial threads at key points to reinforce your web.

EXTENSIONS

1. Watch FRONTIERS and note the steps an orb-weaving spider follows to make a web. How does the spider's procedure compare with yours?

FIGURE 1

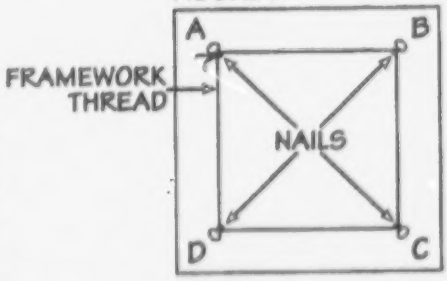


FIGURE 2

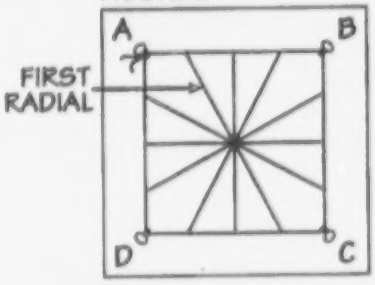
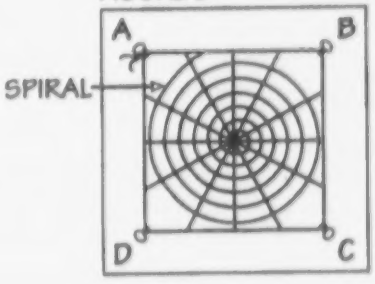


FIGURE 3



2. The shape of an orb web is considered an example of an Archimedes' spiral (named after the Greek mathematician who studied spirals extensively), because it spirals out in an even manner. Other spiral shapes found in nature include the fossilized ammonite, a sunflower and a spiral galaxy. Can you find other examples?
3. The spiral is the sticky part of the spider's web. Scientists do not agree about why spiders can avoid becoming trapped in their own webs. Use the Internet to research theories about why spiders don't get stuck in their own webs.

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Web Research Lab

As you see on FRONTIERS, some types of spiders rely on webs to help catch their prey. Some webs catch insects, while others are designed to catch birds and bats!

Spiders have had 400 million years to perfect their silk, known for its elasticity and strength. Silk is secreted by the silk glands or spinnerets. Many species produce up to seven different kinds of silk, each with different properties, each produced by a different silk gland. There are silks for different parts of a web, for egg sacs and for snares, but the strongest kind is dragline silk, used to make the frame of a web and the line a spider uses to dangle from its web. Scientists and engineers are very interested in synthesizing spider silk, which they hope could be used for parachutes, bullet-proof vests and even surgical sutures.

In this activity, you'll define properties of different threads and then use your results to select the best thread to design a web to capture a specific prey. You'll first need to test various types of thread to see which is the strongest.

MATERIALS

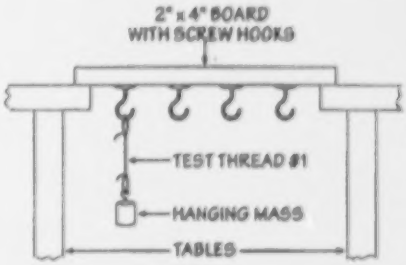
- ☐ thread test set-up made from a piece of 2" x 4" board and 4 screw hooks. Set this between two tables (see diagram above).
- ☐ samples of thread from fabric store (Select threads made from different fibers, with a mix of thickness and elasticity.)
- ☐ hooked mass set 10g to 1000g (If not available, devise a paper clip hook with fishing weights.)

PROCEDURE

1. Measure approximately 20cm of each thread to be tested. Assign a number to each thread so that you can keep track of which is which. Create a data table like the one below and record the number and material of each thread.
2. Tie a loop in each end of the thread. Loop one end of the thread around one of the screw hooks so it hangs freely (see test set-up diagram above).
3. Begin with the lightest mass and carefully hang it on the first thread to test it. If the thread does not break, add more mass. Repeat until the thread breaks.

SAMPLE DATA TABLE

TEST #	MATERIAL	MASS	NOTES
1	Rayon	500g	Stretched 2 cm
2	Cotton	450g	
3	Elastic	650g	Stretched 20 cm
4			
5			
6			
7			



SCIENTIFIC AMERICAN FRONTIERS

SPIN, SPIN, SPIN...
(CONTINUED)

4. In your data table, record the greatest mass the thread supports without breaking. Record any other observations you make.
5. Repeat Steps 2 through 4 for each thread sample.

QUESTIONS

1. Which thread supported the most mass? The least?
2. Which thread would be the best to catch large prey, like a bird or bat? Explain.

Challenge: Could You Survive as a Spider?

For this challenge, you'll need more thread to build webs, a golf ball and a test apparatus to hang webs from (a ring stand and 14cm ring work well). You'll also need to use a balance (pan, triple beam or electronic) to determine the mass of each web. Or, designate the winner as the web using the least thread.

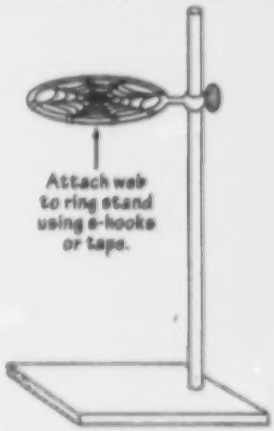
Work in teams of two or more to attempt the following challenges. Webs must be attached to the test apparatus and cannot be adjusted after they are set up.

CHALLENGE 1

Design the lightest web that will support a golf ball. The team that designs the lightest web to support the ball wins.

CHALLENGE 2

Design the lightest web that will catch and hold a golf ball dropped from the greatest height. Start with a drop of 20cm for the first trial. If the web catches and holds the golf ball, increase the drop height by 5cm for each additional trial.



QUESTIONS

1. The challenges required different web designs. How do various spiders' webs differ based on the challenges that nature presents?
2. You weren't allowed to adjust your web once it was set up. How often do spiders tend to adjust their webs?

EXTENSIONS

1. Find out the results of a ground-based experiment designed to see how spiders might behave in space:
   geocities.com/CapeCanaveral/Launchpad/3877/
2. Conduct your own experiment about the biological clock in orb-weaving spiders:
   www.cbt.virginia.edu/olh/middle/activ_m/spider.html
3. Check out the silk glands of orb weavers:
   www.biochem.vt.edu/protein_tut/glandtxt.html

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The SCIENTIFIC AMERICAN FRONTIERS broadcast schedule *is now available online!*

The FRONTIERS website on PBS Online makes it easy to find episodes of FRONTIERS airing in your area and confirm your local broadcast schedule. A complete schedule — including current episodes and rebroadcasts of shows that have already aired — is available online at:

www.pbs.org/saf/

(click "Schedule"). Select your metropolitan area or the episode you're looking for and you'll receive a schedule for the next two weeks of FRONTIERS programming! The FRONTIERS website also features activities, teaching guides Q&A with scientists and other information for current and past episodes. Visit us on the web!

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SCIENTIFIC AMERICAN FRONTIERS

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900 Series (1998-99)

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SCIENCE IN PARADISE SHOW 901 • OCTOBER 1998																						
Turtle Travels	12:28	•	•				•	•	•			•			•				•		•	•
Paradise Postponed	9:15				•	•	•	•		•						•			•		•	
The Pan Man	10:28				•	•					•		•			•	•		•		•	
Big Dish	7:57				•	•	•				•		•			•	•		•	•	•	
Dust Busting	11:02		•			•	•	•		•		•		•	•				•			
JOURNEY TO MARS SHOW 902 • NOVEMBER 1998																						
Out of Thin Air	8:50			•	•	•	•	•								•			•	•	•	
NASA's Way to Mars	9:35				•	•	•									•	•		•	•	•	
Why Go to Mars?	8:29		•		•	•	•	•			•	•				•	•		•	•	•	
We're on Our Way	11:02	•	•			•	•			•	•	•		•		•	•	•	•	•	•	
Houston, We've Had a Problem!	4:00				•	•	•				•							•	•	•	•	
Getting There	8:08	•	•			•	•	•				•	•	•		•	•	•		•	•	
ANIMAL EINSTEINS SHOW 903 • JANUARY 1999																						
If Only They Could Talk!	9:59	•	•			•			•	•	•	•	•					•				•
Who Needs Words, Anyway?	10:47		•			•			•		•	•						•				•
Number Crunchers	7:15		•			•			•			•	•					•				•
Figure That One Out	7:43		•			•			•			•	•					•				•
No Fools About Tools	4:46		•			•			•		•	•	•					•			•	•
Thinking About Thinking	10:20		•			•			•		•	•						•	•			•
LIFE'S LITTLE QUESTIONS SHOW 904 • FEBRUARY 1999																						
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Spin, Spin, Spin . . .	10:38	•	•	•	•				•			•									•	•
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Spider Canyon	12:10	•	•				•	•	•													•
Amazon Tales	10:33	•	•					•	•										•			•
Arachnophobia	9:24	•	•		•					•	•	•		•				•	•		•	•

For more information on the SCIENTIFIC AMERICAN FRONTIERS School Program, write to 105 Terry Drive, Suite 120, Newtown, PA 18940-3425, e-mail saf@pbs.org or call 800-315-5010. Videotapes of past shows may be purchased ($21.97 per one-hour show); call 800-315-5010.

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SEE IT ON PBS

SCIENTIFIC AMERICAN FRONTIERS 900 Series

SCIENTIFIC AMERICAN FRONTIERS is the prime-time PBS series hosted by Emmy Award-winning television star and science enthusiast Alan Alda. Each hour-long show explores intriguing science stories, featuring topics in the fields of human and animal psychology, medicine, genetics, interplanetary exploration and more.

Remember that GTE Corporation, the series underwriter, grants educators free off-air videotaping rights in perpetuity for classroom use of FRONTIERS. Educators may record each show when it airs on PBS and save the videotapes to use whenever and wherever appropriate in the curriculum.

Science in Paradise

SHOW 901 • ORIGINAL AIR DATE: OCTOBER 1998

Dive into the warm, inviting waters of the Caribbean and find out what scientists are learning about this beautiful region. The appearance of paradise can be deceptive. Asteroids from outer space and a devastating volcano on Montserrat are reminders of possible dangers that exist even here. While vacationers enjoy the beaches, science is helping restore a turtle population and tuning into the universe.

Journey to Mars

SHOW 902 • ORIGINAL AIR DATE: NOVEMBER 1998

Sometime in the first decade of the 21st century, people may take off on a mission to the red planet. But how will they get to Mars? How will they adapt to microgravity for such a long journey? And what will they find when they land? Will they uncover any evidence of life? Find out what scientists are doing to solve these problems.

Animal Einsteins

SHOW 903 • ORIGINAL AIR DATE: JANUARY 1999

Can chimps count? Do they think? What about birds and sea lions, or tamarins and other primates? What's going on inside their heads? DNA research reveals that people and primates are closely related genetically. Find out what else science is learning about the mental lives of animals. Perhaps they are smarter than we think they are — and maybe we can learn something from them.

Life's Little Questions

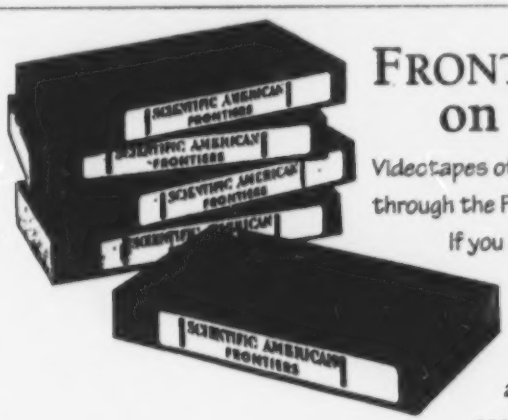
SHOW 904 • ORIGINAL AIR DATE: FEBRUARY 1999

Why are peppers hot? Why does traffic jam? The search for answers to these and other questions takes scientists and host Alan Alda in surprising directions. Even a seemingly trivial question — "Why do coffee stains form as they do?" — becomes a complex exploration. In the process of looking for answers, one question leads to many others, suggesting that no question is too small.

Spiders!

SHOW 905 • ORIGINAL AIR DATE: APRIL 1999

Spiders have been around for more than 400 million years, long enough to evolve ingenious solutions to any challenges that might arise. Meet some of the world's clever arachnids, from garden spiders that weave complicated orb webs to a newly discovered tarantula species. Observe cyberspiders that exist only inside computers, and find out how virtual reality is used to treat arachnophobia.



FRONTIERS on Videotape

Videotapes of past shows are available through the FRONTIERS School Program. If you missed a show or want to complete your FRONTIERS videotape library, call 800-315-5010. Tapes are $21.97 each. (Orders accepted with purchase order, credit card or check.) Teaching guides for past shows are available on the FRONTIERS website on PBS ONLINE: www.pbs.org/saf/.

Let us hear from you!

Tell us what you think about the FRONTIERS School Program.
You can contact us . . .

By mail:
SCIENTIFIC AMERICAN FRONTIERS
105 Terry Drive, Suite 120
Newtown, PA 18940-3425

By phone:
800-315-5010

By e-mail:
saf@pbs.org

Or visit us online:
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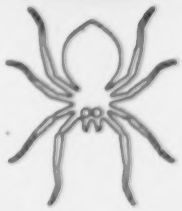

SONG AND DANCE

Meet a jumping spider named after the character Portia in Shakespeare's *The Merchant of Venice*, for her habit of deceiving her enemies. Another jumping spider demonstrates an affinity for watching TV, much to the surprise of arachnologists studying her behavior. Scientist Dave Clark suspects he could be seeing the first stage of an evolving spider species.

Spiders Around You

Spiders seem to be everywhere! Even when we don't see the small arachnids, we see their telltale webs woven in corners and crevices inside and draped from branches and bushes outside. Spiders are abundant. More than 1 million spiders might be found in a one-acre grassy field. They are found just about anywhere, from your house and garden to the 22,000-foot level on Mount Everest. Scientists estimate that the 39,000 known species represent only a fraction of the spider species on Earth.

In this story, we meet jumping spiders, members of the *Salticidae* family. The first is *Portia fimbriata*. The *Portia* genus contains about 15 jumping spider species and is named for the deceitful ploys it uses in hunting and catching its prey. The second spider in this story is *Maevia inclemens*.

Jumping spiders are hunters that stalk their prey and pounce from a distance. Many jumping spiders can be distinguished by two large headlamp-like eyes on the front of their faces and six smaller eyes, arranged on either side of the two big eyes and on top of their heads. Their eight eyes give them excellent vision, unlike web-weaving spiders.

What spider species live near you? In this activity, you will research the types and population density of spiders that live around you.

SEE PAGE 11

Stim Wilcox of University of Binghamton and **David Clark** of Alma College answer your questions online. **www.pbs.org/saf/spiders.html**

MATERIALS

- ☐ research materials, such as field guides or other books about spiders
- ☐ magnifying glass
- ☐ graph paper
- ☐ pencil

PART 1: BACKGROUND RESEARCH

Research spiders that live in your area. Learn to recognize the different species and their webs. Start with a local nature center, county extension office, garden club, biology department at a college, even a zoo, if you live near one. Audubon, Peterson's and Golden Press publish field guides that identify species and their habitats.

PART 2: SPIDER HUNT

1. Select an area where spiders live.
2. Calculate the total area in which you will conduct your search.

   (TOTAL AREA = LENGTH x WIDTH)
3. Create a scale representation of your search area on graph paper.
4. Create symbols for each type of spider and spider web that can be found in the area.
5. Using a field guide and magnifying glass, search for evidence of spider life. Document evidence of each species and where it is found on your area map. Differentiate between species when possible.

PART 3: ANALYZE YOUR DATA

1. Population density refers to the number of individuals in an area. Determine the population density by using the following equation:

$$\text{POPULATION DENSITY} = \frac{\text{NUMBER OF INDIVIDUALS}}{\text{SIZE OF AREA}}$$

For example, 10 orb spiders live in a barn 100 square meters. Population density equals 10 spiders divided by 100m², or 0.1 spiders/square meter.

2. Place your results in a data table similar to the one below:

POPULATION NAME	NUMBER OF ORGANISMS	POPULATION DENSITY

QUESTIONS

1. Place all of the spider species within a food web. What do you think would happen if you removed one component of the web?
2. Environmental conditions that keep a population from increasing in size and affect the balance of an ecosystem are called limiting factors. What limiting factors might affect spiders where you live?

EXTENSIONS

1. Find out what roles spiders play in the ecosystem. Why are most spiders considered beneficial to people?
2. For more about jumping spiders, see these websites:

   137.142.42.104/StudentArea/KLangdon/INTRO.html

   Salticidae home page:

   spiders.arizona.edu/salticidTOLhome.html
3. Search the Web to find out more about the spiders that live in your state or in the U.S. Use your findings to create a spider map showing the different species that flourish in the areas you studied.

FACE OF A JUMPING SPIDER

With eight eyes, jumping spiders have excellent eyesight — among the best in invertebrate animals. Many species can recognize prey or other spiders 4" to 8" away. They can also change the color of their eyes.

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SCIENTIFIC AMERICAN FRONTIERS

SPIDER CANYON

Arachnologist Susan Riechert has been studying spiders in her large-scale natural lab in Arizona for many years. Recently, she began to observe that the union of aggressive male spiders from the desert with timid spiders from the river is producing a super-aggressive hybrid spider with very low survival rates. Riechert suspects she may be witnessing evolution as it happens.

Spider Trading Cards

Funnel-web spiders have evolved many unique adaptations that enable them to survive. From behavioral changes like hiding in webs to escape the heat of the day, to physical modifications like those needed to spin funnel-shaped webs, adaptations are critical to a species' success.

In this activity, you'll make a set of spider trading cards that will include information about a spider's behavior, habitat and adaptations. Making these cards is a good way for you to apply your research and observation skills. If you wish, make the cards in the form of a book. Or, if you have the capacity, scan the cards and include them on your school's website (see Step 3). The same technique can be applied to the study of any animal species.

MATERIALS

☐ pencils or other drawing instruments ☐ blank index cards or other card stock

PROCEDURE

1. **OBSERVATIONS.** Choose an organism to research or observe. Spiders are the obvious choice, but if you wish, select another animal. (If you cannot observe animals outdoors because of weather or locale, choose a dog, cat, hamster or other pet to observe.) Take notes about your subject's appearance and activities. Do you observe any behavior that could be considered an adaptation to the animal's environment? For example, if you observe a spider weaving a web, how does the web help the spider survive in its habitat?
2. **MAKE A TRADING CARD.** On one side of an index card, list information about the animal's vital stats, including its common and scientific names, size, habitat, predators, feeding habits and any interesting behavior or adaptations. (Use the Internet or other resources to supplement the information you learned by observing, if needed.) Place a drawing or photograph on the other side of the card, and laminate your card if you wish. To find more information about spiders online, visit:

   dns.ufsia.ac.be/Arachnology/Arachnology.html

   www.york.biosis.org/zrdocs/zoolinfo/grp_arac.htm

SEE PAGE 11

Susan Riechert of University of Tennessee answers your questions online.
www.pbs.org/saf/spiders.html

3. **SPIDERS ON THE WEB.** Scan your cards into a computer and use them to create a page on your school's website that displays your research.
4. **FRONTIERS CARDS.** Make a set of trading cards that includes the spiders seen in this episode. Alternatively, create trading cards for other episodes of FRONTIERS (**Animal Einsteins**, Show 903, for example) and archive with the videotape library.

BLACK AND YELLOW ARGIOPE SPIDER
Argiope aurantia

COMMON NAME: black and yellow garden spider

SCIENTIFIC NAME: Argiope aurantia

SIZE: female, 19 to 28 mm long; male, 5 to 8 mm long

HABITAT: gardens and backyards in temperate areas of North America

BEHAVIOR & ADAPTATIONS: Like most other Argiopes, it weaves an orb web. Many Argiopes decorate their webs with special silk in a zigzag pattern that reflects UV light. Scientists believe the UV light attracts insects. This species has distinctive markings, which are different from markings on other black and yellow Argiopes (like the banded Argiope or Bruennich's Argiope). Most Argiopes have poor vision, but are able to sense vibrations of other spiders or prey on their webs. This spider has wrapped its victim in silk. Typically, the A. aurantia hangs head down from the center of its web.

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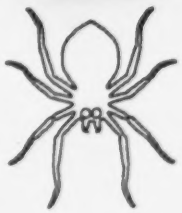
SCIENTIFIC AMERICAN FRONTIERS

AMAZON TALES



FRONTIERS travels to Ecuador, where arachnologist Leticia Avilés explores some of the world's largest spider webs, inhabited by unusual colonies of thousands of social spiders. We also meet tarantula expert Rick West, who introduces us to native tarantulas and to a newly discovered species, named after host Alan Alda and seen here on TV for the first time.

Design a Spider

In this story, we meet several spider species and learn about their adaptations to the world around them. The spiders Leticia Avilés studies, *Anelosimus eximius*, live in large colonies. This social behavior is unusual for spiders, but may be advantageous to the species' survival. Also featured in this story are several tarantulas, whose adaptations include the ability to spin silk and a defense of releasing tiny hairs that irritate an enemy's skin. In this activity, you'll design a new species of spider, with adaptations required to survive in a particular habitat.

MATERIALS

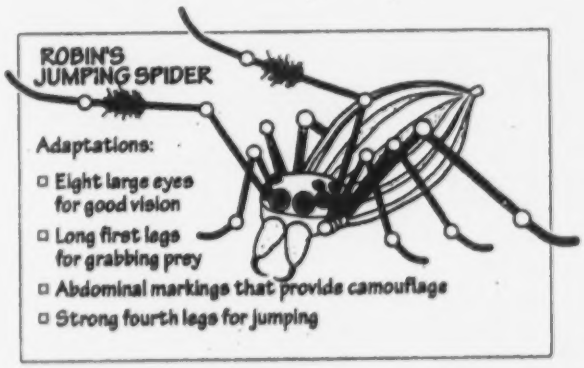
- ☐ research materials (field guides)
- ☐ graph paper ☐ pencil
- ☐ ruler ☐ clay

PART 1: RESEARCH

1. **STRUCTURE.** Use your textbook or other resources to find out more about spider anatomy, behavior, habitat, adaptations, food, defenses, enemies, silk and webs. Guide books like those published by Golden Press *(Spiders and Their Kin)*, the Audubon Society, Peterson's or the Dorling Kindersley Eyewitness series are useful.
2. **SHAPE AND SIZE.** Research spiders of varying sizes and shapes. Determine which sizes and shapes are advantageous in different circumstances and habitats.
3. **DEFENSES.** Research how different types of spiders protect themselves from their enemies. Determine the relationships between their structure, habitat and type of enemies.

SEE PAGE 11

Leticia Avilés of University of Arizona and tarantula expert **Rick West** answer your questions online. **www.pbs.org/saf/spiders.html**


ROBIN'S JUMPING SPIDER
Adaptations:
☐ Eight large eyes for good vision
☐ Long first legs for grabbing prey
☐ Abdominal markings that provide camouflage
☐ Strong fourth legs for jumping

PART 2: PLAN YOUR DESIGN

1. First, determine the type of habitat your spider will live in. Consider the following factors:
   - ☐ Availability of food and water
   - ☐ Climate
   - ☐ Predators
   - ☐ Any other important factors?
2. Determine what types of enemies your spider might encounter. Will your spider choose to fight or flee from its enemies? Will it use poison or another defense against enemies? How strong will its poison be? Will this species require any other natural defenses?
3. Choose how your spider will survive in its habitat. Based on its prey or food source, will it be diurnal or nocturnal? Based on its environment and enemies, will it live above or underground? Will it create its own home or will it move into a structure that already exists?
4. Based on your spider's lifestyle, food sources and other needs, determine what size it will be. Then, based on its size and needs, determine its structure. How will it achieve gas exchange and produce silk? What will be the relationship between the size of its body and legs?

PART 3: IMPLEMENT YOUR DESIGN

1. Design a two-dimensional model. Using graph paper, draw a scale model of your spider. Remember to include all structures necessary for survival.
2. Create a three-dimensional model. Using clay or any materials you may have handy, create a replica of your spider design.
3. Give your species a name.

QUESTIONS

1. What are the different spider adaptations you observed in this episode of FRONTIERS?
2. How would the adaptations you gave your spider help it to survive? Does your spider face any disadvantages based on its adaptations?

EXTENSIONS

1. Create a diorama that includes the habitat and food chain in which your spider lives.
2. What other animals have exoskeletons? What are the environmental advantages and disadvantages for an animal that has an exoskeleton?
3. Compare spiders to other arthropods. What do they have in common? What differences do they have? Create a visual aid that demonstrates the comparison.
4. To learn more about tarantulas, a popular pet, visit the American Tarantula Society online at:

   torgo.cnchost.com/ats

   To see old woodcuts and learn more about tarantulas and other arachnids, go to:

   www.acs.ucalgary.ca/~schultz/

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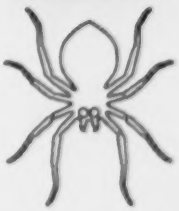
SCIENTIFIC AMERICAN FRONTIERS

ARACHNOPHOBIA



Thanks to a story that originally aired on FRONTIERS two seasons ago, a Seattle woman with an extreme case of arachnophobia is now able to live a normal life. As you see in this episode, arachnophobia can be treated using virtual reality therapy. We'll meet Hunter Hoffman, who worked with the woman's therapist, Al Carlin, to develop a virtual SpiderWorld, complete with virtual spiders.

Facing Up to Fear

A phobia is an intense fear of a specific thing, like spiders. It's normal to be afraid of some things, but a phobia is different from simply being afraid. A phobia is a fear so strong that it affects one's quality of life. For example, the woman featured in this episode of FRONTIERS was so afraid of encountering a spider that she became hesitant to leave her house.

One treatment that has been shown to help phobic patients is desensitization, in which the patient is gradually exposed to the feared object or situation. The advantage of using virtual reality for desensitization therapy is that VR is used in a clinical setting and can be controlled by the therapist or patient. As you see in this episode of FRONTIERS, as Joanne was systematically exposed to the experience of seeing and touching spiders through VR therapy, she gradually became more comfortable with spiders.

EXTENSIONS

1. Brainstorm other medical applications of virtual reality therapy. You may want to refer to the story about using VR to treat fear of heights ("Virtual Fear") in **21st Century Medicine** (Show 605).
2. Find out more about Hunter Hoffman's research projects in virtual reality at:

   www.hitl.washington.edu/

SEE PAGE 11

Hunter Hoffman of University of Washington and clinical psychologist **Al Carlin** answer your questions online.
www.pbs.org/saf/spiders.html

3. Investigate the phenomenon of arachnophobia and theories about why it exists.
4. CONTEST IDEA: Who can find and photograph the largest spider web? Without disturbing the spider, lightly mist the web with water before photographing.
5. Research the origins of references to spiders in popular movies, stories, songs, myths, poems and nursery rhymes. For example, Miss Muffet was a real girl. Her father, Thomas Muffet, made his daughter eat mashed spiders when she was sick. This remedy was allegedly a common treatment for colds 200 years ago.
6. Play Spider Jeopardy! Have students work in teams to research spider facts and write answers and questions in classic Jeopardy! format. Then use the questions for team competition. The Spider Jeopardy! quiz below can help students get started.

Spider Jeopardy!

Test your knowledge of spiders by providing the "questions" to these clues, in classic Jeopardy! format.

1. **ANSWER:** While insects have six of these, spiders have eight.
   QUESTION:

2. **ANSWER:** Produced by a spider's spinnerets, it is five times stronger than steel; researchers are trying to synthesize it in the lab.
   QUESTION:

3. **ANSWER:** Unlike humans and other mammals, spiders have this kind of skeleton.
   QUESTION:

4. **ANSWER:** This animal phylum includes spiders, insects, crustaceans and other invertebrates.
   QUESTION:

5. **ANSWER:** The bite of either of these two spiders found in North America can be fatal.
   QUESTION:

6. **ANSWER:** People once believed the bite of this big, hairy spider could be cured only by dancing the tarantella.
   QUESTION:

7. **ANSWER:** Spiders, daddy-longlegs, ticks, scorpions and mites belong to this class of animals.
   QUESTION:

8. **ANSWER:** All spiders spin silk. Not all spiders make these.
   QUESTION:

9. **ANSWER:** In classic Greek mythology, this young girl won a weaving contest with the goddess Athena, who turned the girl into a spider.
   QUESTION:

10. **ANSWER:** Spiders spin many kinds of webs. Identify two types seen in this episode of FRONTIERS.
    QUESTION:

Spider Jeopardy Questions: 1. What are legs? 2. What is silk or spider silk? 3. What is an exoskeleton? 4. What are arthropods or Arthropoda? 5. What are brown recluse or black widow spiders? 6. What is a tarantula? 7. What are arachnids or Arachnida? 8. What are water? 9. Who was Arachne? 10. What are funnel and orb webs?

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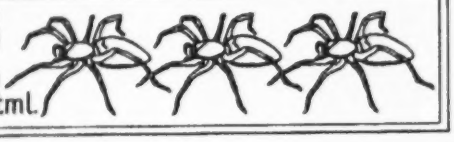
Selected Websites for Show 905



Visit these sites to learn more about topics on **Spiders!** You can find more related links online at www.pbs.org/saf/spiders.html.

General Knowledge of Spiders

dns.ufsia.ac.be/Arachnology/Arachnology.html

Arachnology home page. Links to arachnological resources. Taxonomy, biogeography, scientists, educational projects.

members.tripod.com/~salticidae/

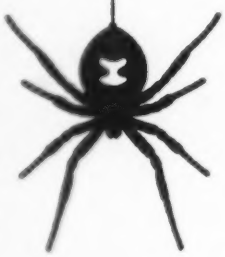
Spider Web Ring for arachnophiles all over the world. Sites by and for schools. Care and feeding of spiders.

dns.ufsia.ac.be/Arachnology/Pages/Kids.html

Links to spider sites especially interesting for students.

www.powerup.com.au/~glen/spider.htm

Activities, first aid, class projects, links, poems. (Hosted by an Australian school.)



tarantulas.inetc.net/

Spider picture gallery, zoos, myths, pet care.

home.ican.net/~dshort/spiders.html

Spiders and Insects page. Links and info, pictures, entomological societies, biodiversity, educational information and more.

www.srv.net/~dkv/hoboindx.html

The Hobo Spider website. History, bite prevention and treatment, photos. Map and information on other venomous U.S. spiders.

Spiders in the Show

torgo.cnchost.com/ats

American Tarantula Society.

www.scit.wlv.ac.uk/~cm1906/tarantula.html

The Tarantula's Nest. Care, feeding, biology and habits of tarantulas. Tarantulas as pets.

spiders.arizona.edu/nasaltshome.html

Jumping spiders of America north of Mexico.

spiders.arizona.edu/salticidae/++salticidae/anatomy/anatomy.html

Anatomical tour of a jumping spider.

grad.admin.arizona.edu/idps/insc/leticia_aviles.html

Work by Leticia Avilés on social spiders and evolution of social behavior.

www.xs4all.nl/~ednieuw/Spiders/spidhome.htm

Hundreds of spider photos, plus detailed drawing of orb-web construction.

Arachnophobia

www.hitl.washington.edu/

Hunter Hoffman's VR projects at the Human Interface Technology Lab.

dns.ufsia.ac.be/Arachnology/Pages/Phobia.html

Current research in VR and other treatments.

ASK THE Scientists Online

Explore the world of Spiders! with FRONTIERS Online!

After **Spiders!** airs, specialists from the show will answer questions about their work. The scientists featured below will be available from **April 21 to May 7, 1999**. To participate in Ask the Scientists, visit FRONTIERS online at:

www.pbs.org/saf/spiders.html

SPIN, SPIN, SPIN...

Fritz Vollrath of the University of Aarhus in Denmark answers your questions about how spiders build their webs – creations he calls "the perfect lightweight structure."

SONG AND DANCE

Ask Stim Wilcox of the University of Binghamton about the clever and cunning *Portia fimbriata* spider, and send questions to David Clark of Alma College about the fascinating *Maevia inclemens*.

SPIDER CANYON

Susan Riechert of the University of Tennessee tells you more about the 1,500 spiders in her natural laboratory – and how they may give us a glimpse of evolution in action.

AMAZON TALES

Leticia Avilés of the University of Arizona shares her knowledge about spider colonies in Ecuador, while Rick West shares his enthusiasm for tarantula species – including one named after Alan Alda.

ARACHNOPHOBIA

Hunter Hoffman of the University of Washington and Al Carlin, a clinical psychologist, explain how their collaboration and use of virtual reality helped ease a woman's fear of spiders.

HOW TO "ASK THE SCIENTISTS"

Visit SCIENTIFIC AMERICAN FRONTIERS on PBS Online at www.pbs.org/saf/spiders.html and click on "Ask the Scientists" to send your question(s). Scientists' answers will be posted online for FRONTIERS viewers to read.

Remember to e-mail your questions by May 7, 1999!

PBS online

NOTE: AVAILABILITY OF SCIENTISTS IS SUBJECT TO CHANGE. DEPENDING ON VOLUME OF QUESTIONS RECEIVED, ONLY SELECTED QUESTIONS MAY BE ANSWERED.

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SCIENTIFIC AMERICAN FRONTIERS

Watch It On PBS

SCIENTIFIC AMERICAN FRONTIERS airs on PBS with five new programs each season, October through April. Check local listings or the schedule on the FRONTIERS website (www.pbs.org/saf/) to find FRONTIERS programs airing in your area, including rebroadcasts of popular episodes. Enjoy the summer – we'll be back next fall with five exciting new episodes!

1998-99 Season Index inside!

SHOW 901: Science in Paradise

***INTERNATIONAL SPECIAL!* WEDNESDAY, OCTOBER 7, 1998**

Dive into the beautiful waters of the Caribbean and find out what scientists are learning about the science of paradise, from sea turtles to a volcano.

SHOW 902: Journey to Mars

WEDNESDAY, NOVEMBER 11, 1998

3 . . . 2 . . . 1 . . . Blast off to Mars! Early in the 21st century, humans may take off on the first mission to the red planet. Learn about scientists' exciting projects, from inflatable habitats to the search for Martian life.

SHOW 903: Animal Einsteins

WEDNESDAY, JANUARY 20, 1999

Dr. Dolittle isn't the only person who talks to the animals. Scientists tell us we can learn much from our furry, feathered and finned friends.

SHOW 904: Life's Little Questions

WEDNESDAY, FEBRUARY 24, 1999

What makes hot peppers hot? Why do traffic jams happen? What's the best way to combat jet lag? Join host Alan Alda in a scientific quest to answer some of the little questions that affect us, sometimes in big ways.

THIS ISSUE SHOW 905: Spiders!

WEDNESDAY, APRIL 21, 1999

Meet some of the 39,000 known spider species — including a few of the world's largest tarantulas, and cyberspiders that live inside computers. And, learn about a high-tech solution to the ancient fear of spiders, arachnophobia.

ALAN ALDA, meet Rosie the Mexican red-kneed tarantula, one of the interesting arachnids featured in this episode of SCIENTIFIC AMERICAN FRONTIERS, all about Spiders!

SEE IT ON PBS

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INSIDE:
Requested Teaching Materials for SPIDERS!

AIR DATE:
April 21, 1999

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Discover the Galapagos

WITH SCIENTIFIC AMERICAN FRONTIERS

The name Galapagos evokes images of an exotic and remote island environment, an amazing diversity of creatures and, of course, Charles Darwin's historic visit in 1835 aboard the H.M.S. Beagle.

SCIENTIFIC AMERICAN FRONTIERS is delighted to invite you and your students to join us for a cyber field trip to the Galapagos Islands December 6-13, 1998. This exciting trip is a first-ever chance to go behind the scenes during the making of an episode of SCIENTIFIC AMERICAN FRONTIERS that will air during the 1999-2000 school year. It's all happening live on the Web this December at www.pbs.org/saf/galapagos.html — with pre-event content available beginning October 20.

This educator's guide will help you and your students get set for our adventure to this extraordinary archipelago. During the trip, you'll have a chance to interact with FRONTIERS host Alan Alda, the expedition team and your teacher ambassador Sherri Steward as they investigate the islands' intriguing species, learn about scientific research projects in the region and understand more about how the Galapagos inspired Charles Darwin's groundbreaking theory of evolution.

Join the Cyber Field Trip!

FRONTIERS will be in the Galapagos Islands December 6–13, and you're invited to come along! You can bring the islands to life in your classroom — before, during and after the expedition. Here's how:

- ✓ Photocopy the information, activities and itinerary on this side of the poster to use with your students for classroom discussion, preparation or follow-up activities and take-home projects.
- ✓ Display the poster-map in your classroom to let students know about the trip and our destinations in the Galapagos.
- ✓ Before the trip, visit the cyber field trip website on PBS online: **www.pbs.org/saf/galapagos.html** (available October 20) for pre-event content, background information and resources for additional information, plus a chance for you and your students to e-mail questions to your teacher ambassador.
- ✓ Log on to the site during the expedition (December 6-13) for daily updates, photos, activities and discussion, live from the Galapagos Islands!
- ✓ After the trip, the site will be archived on PBS Online so students can continue to access information and record the data they gather through this expedition. We'll also have an extended Q&A with members of the expedition team.

This cyber field trip is free to schools. Visit www.pbs.org/saf/galapagos.html to register for pre-trip updates!

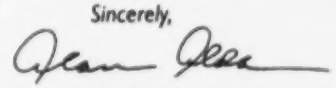
A MESSAGE FROM ALAN ALDA

Dear Educator:

A trip to the Galapagos Islands is a once-in-a-lifetime opportunity to study some of the world's most interesting and exotic wildlife. Animals there have never learned to fear humans — meaning visitors to the islands can get close-up views of creatures like the Galapagos tortoise, blue-footed booby, Galapagos penguin, marine iguana and others.

The Galapagos is a place I've always wanted to visit. This trip with SCIENTIFIC AMERICAN FRONTIERS is especially exciting for me because it gives educators and students in the FRONTIERS School Program a chance to go behind the scenes in the filming of an episode of FRONTIERS for next year — and to experience this fascinating environment where Darwin made his own great voyage of discovery. I hope you will come along.

Sincerely,



Alan Alda

Curriculum Links

PRIMARY LINKS: Biology, Evolution, Life Science

RELATED LINKS: Earth Science, Ecology, Geography, Geology, History, Literature, Social Studies

SCIENTIFIC AMERICAN FRONTIERS

Destination: Galapagos Islands
December 6-13, 1998
www.pbs.org/saf/galapagos.html

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Bienvenidos a Galapagos!

("WELCOME TO THE GALAPAGOS" IN SPANISH, THE LANGUAGE OF ECUADOR AND THE GALAPAGOS ISLANDS)

SCIENTIFIC AMERICAN FRONTIERS

Destination: Galapagos Islands
December 6-13, 1998
www.pbs.org/saf/galapagos.html

SCIENTIFIC AMERICAN FRONTIERS invites you to come along on an expedition to the Galapagos Islands!

Join host Alan Alda, the FRONTIERS crew, scientists, naturalists and your teacher ambassador Sherri Steward for this exciting voyage. To take part, simply log on to the cyber field trip website on PBS Online, **www.pbs.org/saf/galapagos.html**, beginning October 20, when pre-event materials will be available. From December 6-13, 1998, when the crew is live in the Galapagos, every day will bring something new to the site — Sherri will update her e-mail and photo expedition journal daily, and the team will send back video clips of their work in the Galapagos. Scientists on the trip will answer your questions by e-mail. Plus your class can participate in an entire week of interactive activities! Collect data from your local area and log on to compare it with data gathered by Sherri and scientists in the Galapagos!

ITINERARY

Day 1:
Sunday, December 6
Cruise the northwest side of **Santa Cruz**, the only island to see **land iguanas**.

Day 2:
Monday, December 7
Hike on **Hood Island** to observe blue-footed **boobies, marine iguanas, lava lizards** and **sea lions.**

Activity: Water World!
Begin a five-day look at abiotic factors that affect water quality and, in turn, affect the lives of species living in the area. FRONTIERS teacher ambassador Sherri Steward will take water samples at different points on the expedition and determine the water's pH, salinity and dissolved oxygen levels. Follow along by sampling the water in your area and performing qualitative analysis to see how it compares with samples from the Galapagos.

Day 3:
Tuesday, December 8
Morning snorkeling trip on **Floreana** to view **sea lions** and **colorful fish**; afternoon outing to observe **flamingoes** and **turtle nesting areas.**

Activity: Soil Comparison and Analysis
All life forms on Earth depend on soil for their existence. How does the presence of different macronutrients affect soil? Sherri will test soil samples to determine the levels of three macronutrients: nitrogen, phosphorus and potassium. Analyze soil samples from your area to see how they compare to Galapagos soil samples and learn more about the importance of macronutrients. Sherri will provide soil nutrient analysis throughout the week — your class can test samples from different locations each day to come up with a range of soil analyses from your area.

Day 4:
Wednesday, December 9
Morning **whale watch** and **seabird sightings** at **Roca Rodenda**; afternoon trip to **Fernandina** to see **lava lizards** and **flightless cormorants** and to explore **El Niño's effects** on **marine iguanas.**

Activity: Natural Selection and Species Adaptation
The Galapagos Islands are famous for providing the chance to study wildlife adaptation. Learn more about the development of various species — each with unique features that are designed to serve a specific purpose. You'll see a variety of creatures, including some of the many bird species that inhabit the islands.

Day 5:
Thursday, December 10
Morning visit to **Darwin Research Station** on **Santa Cruz** to see the **tortoise breeding program**; afternoon excursion to the highlands to see the **stunted forest, giant pit craters, volcanic tubes** and numerous **finches.**

Activity: Wildlife Taxonomy
To separate and identify different species of wildlife, scientists classify organisms using an ordered system that defines their natural relationship to one another. Learn more about the classification of species, including how DNA sequencing can be used to determine the relationship between different species.

Day 6:
Friday, December 11
Sail to **Tower Island**, right to the middle of its crater for snorkeling to see **Hammerhead sharks** and hiking to see **frigate birds, red-footed boobies** and **gulls.** Also, visit **St. Philips Steps** to see more **seabirds.**

Activity: Biological Communities, Ecosystems and Biomes
Learn about the inter-relationship between living and non-living components of an ecosystem and how a change in one component can affect other parts of the ecosystem. In the Galapagos Islands, El Niño brought more than the usual amount of rain. The rain affected the growth of vegetation, which had an impact on the islands' wildlife. Volcanoes can also affect vegetation growth. Find out more as Sherri investigates the ecosystems at work in the Galapagos, while you investigate your local ecosystems.

Day 7:
Saturday, December 12
Hike at **Bartolome** to admire the view; snorkeling with **penguins** and **sea lions** at **Pinnacle Rock**, then the boat sails for **Santiago, Chile.**

Day 8:
Sunday, December 13
Early morning circumnavigation of **Daphne Major**, then it's time to return home.

Where are the Galapagos Islands?

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Meet the Galapagos Expedition Team

Host
ALAN ALDA
This award-winning actor and science enthusiast is now enjoying his sixth season as host of SCIENTIFIC AMERICAN FRONTIERS. "When I go with the SCIENTIFIC AMERICAN FRONTIERS crew by plane and then by boat to the Galapagos, I hope I'll be taking the audience with us," Alan says. "We'll be travelling where Darwin travelled in a voyage of discovery that has had such an enormous impact on the way we think about life."

Naturalist
LYNN FOWLER
Dr. Lynn Fowler first visited Ecuador and the Galapagos Islands in 1976. She was captivated by the fearless island inhabitants and the stark beauty of the volcanic archipelago. After receiving her master's degree in zoology from the University of Florida, studying sea turtles, she returned to the Galapagos and worked as one of the first female naturalist guides for the Charles Darwin Research Station. Lynn will lead the FRONTIERS expedition to the Galapagos on behalf of Lindblad Special Expeditions, the company hosting FRONTIERS on this trip. Lynn's research projects have covered feral burros and giant tortoises of Volcan Alcedo on Isabela Island, as well as the rainforest white-lipped peccary.

Teacher Ambassador
SHERRI STEWARD
Biology teacher Sherri Steward is no stranger to exotic biology field work. Her areas of study have ranged from bears in Yellowstone National Park to primates in Africa and Borneo. This past summer she was in Lusaka, Zambia, to help teachers at the Bauleni school build flush toilets as a step toward limiting the spread of cholera. The funds for the project came from a year-long fundraising effort Sherri conducted with her ecology students at Grapevine High School in Grapevine, Texas. Sherri is a long-time fan of SCIENTIFIC AMERICAN FRONTIERS and has been honored as a Presidential Award winner (1994), Time Magazine Earth Teacher of the Year (1992) and a GTE GIFT Fellow (1989).

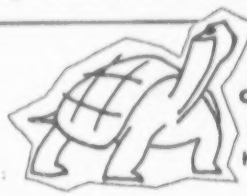
As the FRONTIERS School Program representative in the Galapagos, Sherri will help involve teachers and students across the country in this exciting distance learning event. She'll be in touch every day through an e-mail journal, photos and video clips on the *Destination: Galapagos Islands* website. Before the trip, you can e-mail your questions to Sherri and the team. Your questions may be answered in the team's daily dispatches from the expedition! Plus, throughout the trip, Sherri will conduct scientific field research and upload her data to the website, with interactive activities for teachers and students across the country!

"It's every biologist's dream to be able to go to the Galapagos, because that's where Charles Darwin did his original research," Sherri says. "That means a lot to people in biology — and I'm no different. I'm very excited to be able to serve as an ambassador to the Galapagos for educators and students."

Destination: Galapagos Islands is an extension of the SCIENTIFIC AMERICAN FRONTIERS School Program and website on PBS Online. The series airs on PBS with five new programs each season, October through April. Each hour-long special includes a variety of intriguing science stories based on a single theme. (The Galapagos special will air in the 1999-2000 season.) Educators have free off-air taping rights in perpetuity for classroom use of FRONTIERS programs, and may photocopy all materials in this guide for classroom use.

GTE

The SCIENTIFIC AMERICAN FRONTIERS series and School Program are underwritten by GTE Corporation. To sign up for free teaching materials, call 800-315-5010 or e-mail saf@pbs.org.



Did You Know?
Galapagos is a Spanish word meaning saddle or tortoise. Galapagos turtles have saddle-shaped shells.

Wildlife photos on poster front: © Sven-Olof Lindblad. Illustration: Rosemary Tottoroco.
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This Galapagos Islands expedition is a project of The Chedd-Angier Production Company in preparation for an hour-long special on the next season of FRONTIERS. Educational materials produced by Media Management Services, Inc.

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A Living Laboratory of Evolution

As Charles Darwin first discovered, the Galapagos Islands are a natural laboratory of evolution in process. This volcanic archipelago is remote — 600 miles west of Ecuador — mostly uninhabited and free of natural predators. Due to this isolation, many of the fascinating species of the Galapagos are endemic, meaning they live nowhere else.

Galapagos Field Guide

You can learn more about the unique flora and fauna of the Galapagos Islands by preparing your own field guide. Here's how:

1. Before the event, form five teams with each team being responsible for preparing a field guide for one of the five major Galapagos islands: Isabela, Fernandina, San Christobal, San Salvador and Santa Cruz.

2. Assign members of your team to research topics to include in your field guide. **Research hint:** The *Destination: Galapagos Islands* website (**www.pbs.org/saf/galapagos.html**) is a great place to find background information and related links to Galapagos sites, and to send questions to members of the expedition team.

3. Here are a few suggested topics to include in your field guide (you may think of more):
   - A description and illustration of the island's physical habitat and how it was formed.
   - Photographs or illustrations of the island's plants, mammals, birds, insects and reptiles.
   - An overview of any ways species have adapted to their habitat.
   - Current research being conducted on the island.

4. When your field guide is complete, present your findings to the rest of the class. Look for instances of how species vary from island to island in the Galapagos and discuss any variations the teams' reports uncover. Can you come up with theories or explanations to account for these variations?

5. Take advantage of the cyber field trip to update your field guide with information sent back by the expedition team — visit **www.pbs.org/saf/galapagos.html** to find photos and additional information on many species the team encounters.

6. Think about endemic species versus introduced species. What plant and animal species are endemic to your geographic area? Which species are introduced?

Understanding Charles Darwin's Theory of Natural Selection

Charles Darwin's visit to the Galapagos Islands in 1835 inspired his Theory of Natural Selection — an explanation of the very process of evolution. The isolation of the Galapagos Islands presented Darwin, and the many scientists who have followed in his footsteps, with an ideal environment to study the adaptations of species.

Darwin studied the islands' finch species, specifically the structure of their beaks and associated feeding behavior. Other examples of evolution in process in the Galapagos include the unique flightless cormorant, which gradually lost functional wings in an environment with abundant shoreline food sources and no predators. Scarcity of vegetation on the volcanic islands likely led the Pleistocene land iguana to seek food along the shoreline and gradually under water, leading to the development of the marine iguana.

The Charles Darwin Research Center in Puerto Ayora provides this outline that helps us understand Darwin's Theory of Natural Selection:

- *In any population of animals, a relatively large number of young are produced. Since not all survive, there must be a struggle for existence.*
- *Within a population there is much variability. Some differences may confer an advantage in the struggle for existence. Those organisms that are best adapted for their environment will survive.*
- *Due to heredity, offspring tend to resemble their parents. Well-adapted organisms tend to have well-adapted offspring. Thus, certain traits become established in the population.*
- *If environmental conditions change, there may be selection for different traits. The variability within a population determines whether it will be able to survive these changes.*

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Classroom Activity

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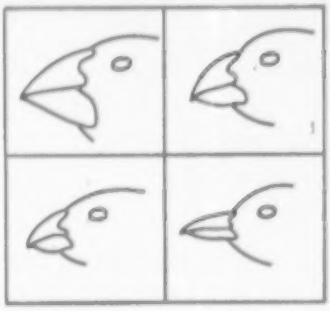
Identifying Organisms: Suppose you found a species of animal that you had never seen before. How would you identify it? Scientists use a tool called a taxonomic key to determine an organism's identity. A key uses a set of statements that describe an organism's appearance to help identify the organism.

Most taxonomic keys are dichotomous, which means they offer only two choices for a specific feature. You select the most correct possibility and are directed to another statement. Eventually, you create a route through a series of statements that ends at the correct name of the unknown organism.

The best way to understand how a dichotomous key works is to try using one. The key below can be used to distinguish between four finch species found on the Galapagos Islands. Use this tool to identify the birds shown below. As you can see, the identification is based upon the features of the birds' bills. Choose one of the finches pictured below and work through the description sets provided to reach a positive identification.



Key to Representative Galapagos Finch Genera

			FINCH IDENTIFICATION
1.	a. The beak is relatively long and slender.	→	***Certhidea sp.***
	b. The beak is relatively stout and heavy.	→	Go to Set 2
2.	a. The bottom surface of lower bill is flat and straight.	→	***Geospiza sp.***
	b. The bottom surface of lower bill has a bend.	→	Go to Set 3
3.	a. The lower edge of upper bill has a distinct bend.	→	***Camarhynchus sp.***
	b. The lower edge of upper bill is mostly flat.	→	***Platyspiza sp.***

Challenge: Examine the animals that are pictured on the front of this poster and on the *Destination: Galapagos Islands* website (**www.pbs.org/saf/galapagos.html**). Write down several identifying characteristics of each organism. Create a dichotomous key that can be used to discover the identity of each animal. To create your key, start with more general descriptions (e.g., the creature is a mammal) and work toward specific characteristics. Exchange keys with a friend. Test these identification tools. Can your key be improved? If so, how?

Extended Key: During the cyber field trip (December 6-13), visit the website to learn about the animals encountered during the expedition. Select several different animals (from any of the islands) and describe the distinguishing characteristics of each. Use this information to create a dichotomous key that can be used to identify each species. Add the information to the field guide you already created (see previous activity).

Taxonomic Adventure!

Visit **www.pbs.org/saf/galapagos.html** to try your hand at species classification through this fun, interactive online activity.

Did You Know?

The Galapagos Islands were once called The Enchanted Islands because they disappeared into the fog at certain times of year and sailors could not find them.

Answers: The finch species shown here are *Geospiza* (top left), *Platyspiza* (top right), *Camarhynchus* (bottom left), *Certhidea* (bottom right).

Studying the Galapagos Across the Curriculum

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Use these activities before, during or after the cyber field trip to extend students' learning about the Galapagos Islands.

HISTORY

- Charles Darwin was the most famous visitor to the Galapagos Islands. Ask students to research Darwin's life and they will discover how a routine landfall at the Galapagos in 1835 to collect tortoise meat for the voyage led Darwin to a lifetime of research. Ask students to find out why Darwin's book *The Origin of Species*, published 24 years after his trip to the Galapagos, was considered the most controversial book ever written.
- Encourage students to read Darwin's own words about his work. His classic works, *Voyage of the Beagle* and *The Origin of Species* are both available online at **www.literature.org/Works/Charles-Darwin/**.
- Darwin forever changed the history of science. Challenge students to discover how other scientists have supported Darwin's theory in the decades since his groundbreaking work.

GEOLOGY

- The Galapagos Islands are one of most active oceanic volcano areas in the world with 53 eruptions recorded from eight of the Galapagos volcanoes. Ask students to find out why this area sees so much volcanic activity. A trip to Volcano World at **volcano.und.nodak.edu/vwdocs/** may help them find answers.
- View slides of the Fernandina Volcano compiled by researchers from the University of Hawaii at **www.geo.mtu.edu/eos/ppages/fern.html**.
- See if your class can stump a volcanologist! Come up with your best question about Galapagos volcanoes and send it to Ask a Volcanologist at **volcano.und.nodak.edu/vwdocs/ask_a.html**.

Did You Know?

Each major island of the Galapagos, with the exception of Isabela, consists of a single large shield volcano. Isabela was formed from six volcanoes joined above sea level.

LITERATURE

- Herman Melville, author of the American masterpiece *Moby Dick*, visited the Galapagos Islands during the whaling era. Students may enjoy reading Melville's allegorical sketches of the Galapagos, "The Encantadas," in *The Piazza Tales*, which reveal nature to be both enchanting and horrifying.
- Recommend *The Beak of the Finch: A Story of Evolution in Our Time* by Jonathan Weiner (Knopf, 1995) to your students. This superb account of evolution and science has been compared to reading a thriller — and it won the 1995 Pulitzer Prize for nonfiction.
- Study of the environment and intriguing species in the Galapagos Islands can provide inspiration for creative writing projects. Have students research and write a poem or descriptive essay about the islands, or a fictitious first-person account in a travel journal or letter home from the islands.

ENVIRONMENTAL ISSUES

- Natural events like El Niño have far-reaching effects on species of the Galapagos, and SCIENTIFIC AMERICAN FRONTIERS investigates these consequences during the *Destination: Galapagos Islands* expedition. Ask the class to brainstorm how the warmer waters caused by the recent El Niño would affect the islands. Then visit the Charles Darwin Research Station (**www.polaris.net/~jpinson/el-nino-1e.html**) for a report on the situation. You'll also be able to read about how the 1982-83 El Niño event affected the islands.
- Although the Galapagos Islands may seem like an untouched paradise, the area is subject to a variety of pressures that threaten its status as a global scientific resource. These include population pressures, tourism, introduced species, poaching and illegal fishing. Ask students to choose one of these threats and research how it affects the islands and what steps are being taken to protect the Galapagos.

Stay tuned
to PBS in 1999-2000 to see the one-hour episode of SCIENTIFIC AMERICAN FRONTIERS filmed during this expedition!

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